DECEMBER 21, 1961

MACHINE DESIGN

A PENTON PUBLICATION — BIWEEKLY

ENGINEERING or MANAGEMENT?

Contents, Page 3

MR. STEVENS RICE
UNIVERSITY MICROFILMS
313 N. FIRST ST.
ANN ARBOR, MICH.

* ASCO MIDGET 3-WAY—ACTUAL SIZE

OVERSIZE EXHAUST

NORMALLY OPEN NORMALLY CLOSED, OR UNIVERSAL OPERATION

MOUNTS IN ANY POSITION

ONLY 2 MOVING PARTS

The ASCO Bulletin 8317 Solenoid Valve provides the fastest cylinder or diaphragm return of any valve its size. For example, at 100 psi a 12" return stroke in a 3" cylinder takes 2½ seconds with the 8317 . . . 7 seconds with a comparable valve. This remarkable 3-way solenoid valve can be substituted for larger, more expensive units normally required to obtain fast return.

In other 3-way valves, the fast rate of flow under pressure usually provides quick operation of the cylinder or diaphragm, but the dissipation of pressure on exhaust results in a slower return stroke. The large exhaust orifice on the Bulletin 8317 (over 7 times greater than the inlet area) quickly vents the pressure, permitting the piston or diaphragm to return rapidly.

The ASCO Bulletin 8317 has only 2 moving parts . . . mounts in any position . . . is available in normally open, normally closed and universal construction . . . with general-purpose, explosion-proof or watertight solenoid enclosures in ¼" pipe size . . . for pressures up to 160 psi . . . for water up to 100° F. or air, gases and light hydraulic oil up to 180° F. It is immediately available from stock, as are other ASCO solenoid valves.

WRITE FOR BULLETIN 8317, providing complete descriptive information on this new, "midget," quick-exhaust 3-way.

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Circle 201 on Page 19

Brushed Nickel-Chrome Plating...
for lasting satin beauty at a practical cost

Notice how the brushed Nickel-Chrome finish on the range top and burner controls of this handsome Sunray range gives it a rich, quality look.

Today's high-fashion tastes are attracted by the subtle charm of this satin finish. Women like the way it blends in with any decor, keeps its glowing good looks for years. Besides being easy to clean, brushed Nickel-Chrome Plating resists abrasion and wear, shrugs off the nicks and scratches of everyday use, gives excellent corrosion protection.

Virtually any major appliance or decorative component can have a fashionable, quality look with brushed Nickel-Chrome Plating. And if you want bright trim, selective buffing will give you brightwork effects without the use of trim hardware.

One more reason why you should specify this remarkable finish: brushed Nickel-Chrome Plating can be applied to all the easy-to-fabricate metals—steel, zinc, aluminum, copper, brass. Less common metals can also be readily plated.

For more information on decorative plating systems, write for the booklet, "The Present Status of Decorative Nickel-Chromium Coatings." A copy is yours for the asking.

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These advances are well worth exploring by designers who need a power pack that is self-contained, economical and nearly noiseless — plus the added advantage of long life with low maintenance costs. It is easy to see then why so many designers are already using lead-acid battery power packs for short haul delivery trucks, industrial trucks, lawn mowers, golf carts, garden tractors, even boats.

Look at the advantages, for instance, that battery power offers in this chipper compact, product of Stuart Motor Co., Inc., of Kalamazoo:

In short-haul, stop-go driving (the kind family cars get the most of) no other car touches a Stuart for economy. It requires no gear-shifting, ever. It doesn't use any fuel when stopped at lights. It gets about 35 miles on a single battery charge — more than the daily mileage of the average suburban car. Batteries like those the Stuart uses have thoroughly proved themselves on delivery trucks. Typical comparison of fuel costs: 1.5¢ a mile for electrics, 7.7¢ for gasoline trucks on same runs.

What could batteries do for *your* product? For technical information and assistance, write: Office of Technical Information, Lead Industries Association, 292 Madison Avenue, New York 17, N. Y.

LEAD INDUSTRIES ASSOCIATION

292 Madison Avenue, New York 17, New York

Look Ahead with Lead

8213

Front Cover: Most engineers, sometime in their careers, face the big question posed by George Farnsworth's cover design: Should I stay in engineering, or try for a career in management? Eugene Raudsepp, on Page 94, gives tests to help arrive at a decision.

THE ELECTRIC MOTOR BOOK

1961 Edition

A basic reference manual on electric motors being mailed separately—Watch for it.

December 21, 1961

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IN THE NEXT ISSUE: Hiring and retaining engineers . . . cumulative effects of tolerances . . . designing sprocket teeth . . . metal casting processes . . . vertically suspended shafts . . . fluid-transfer pumps . . . bellows spring rate.

THE PROFESSIONAL JOURNAL FOR ENGINEERS & DESIGNERS

MACHINE **DESIGN**

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MIDVAC INCREASES STRESS RUPTURE LIFE 6 TIMES FOR JET TURBINE PARTS

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When maximum reliability in the high temperature range and minimum rejects are required that's the place to specify Midvac Steels. These steels assure super alloys of increased tensile, higher impact properties, improved stress rupture strength at elevated temperatures and longer fatigue life.

As an example air melted No. 901 had excellent high temperature strength, but often failed slightly below the required stress rupture hours (15) with little to spare over the minimum ductility requirements. Well over 100 hours can be attained with Midvac melted No. 901.

The Midvac Process of consumable electrode melting eliminates atmospheric contamination, ingot soundness is improved, segregation is reduced, workability is increased and product quality is stepped-up. Midvac Steels are offered in many alloys as billets or forgings to meet the most critical design specifications of jet engine parts, missile and aircraft components and other products requiring properties beyond the capabilities of conventional steels. Let M-H metallurgists help you select the right alloy to meet your product's specifications. Write . . .

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MACHINE DESIGN ENGINEERING NEWS

Chevy Builds a Hot One To Research Ride and Handling

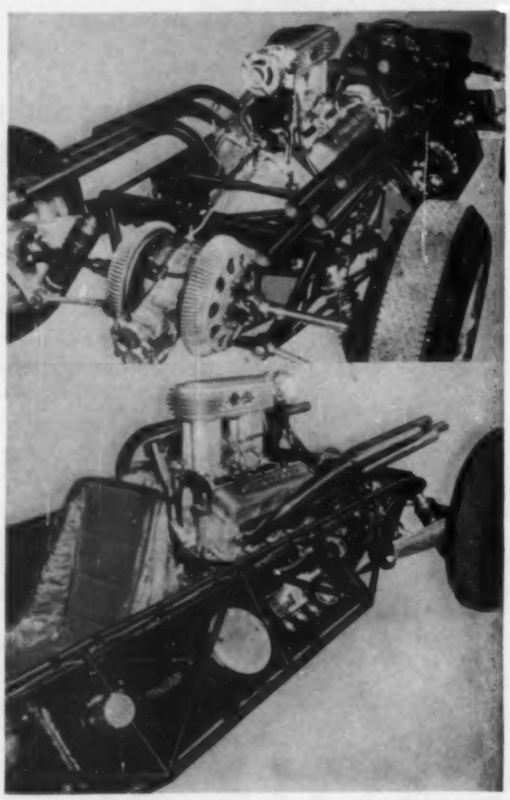
DEVELOPED as a research vehicle for investigating automobile ride and handling phenomena, Chevrolet's CERV I (Chevrolet Engineering Research Vehicle) will be a hot tool in the future design of Chevrolet passenger cars.

A fundamental factor in the design of CERV-I is the visibility afforded by the racing-type body. It completely encloses the engine, transaxle, and engine cooling system, but provides an open cockpit for the driver from which all four wheels are exposed for visual observation during handling studies.

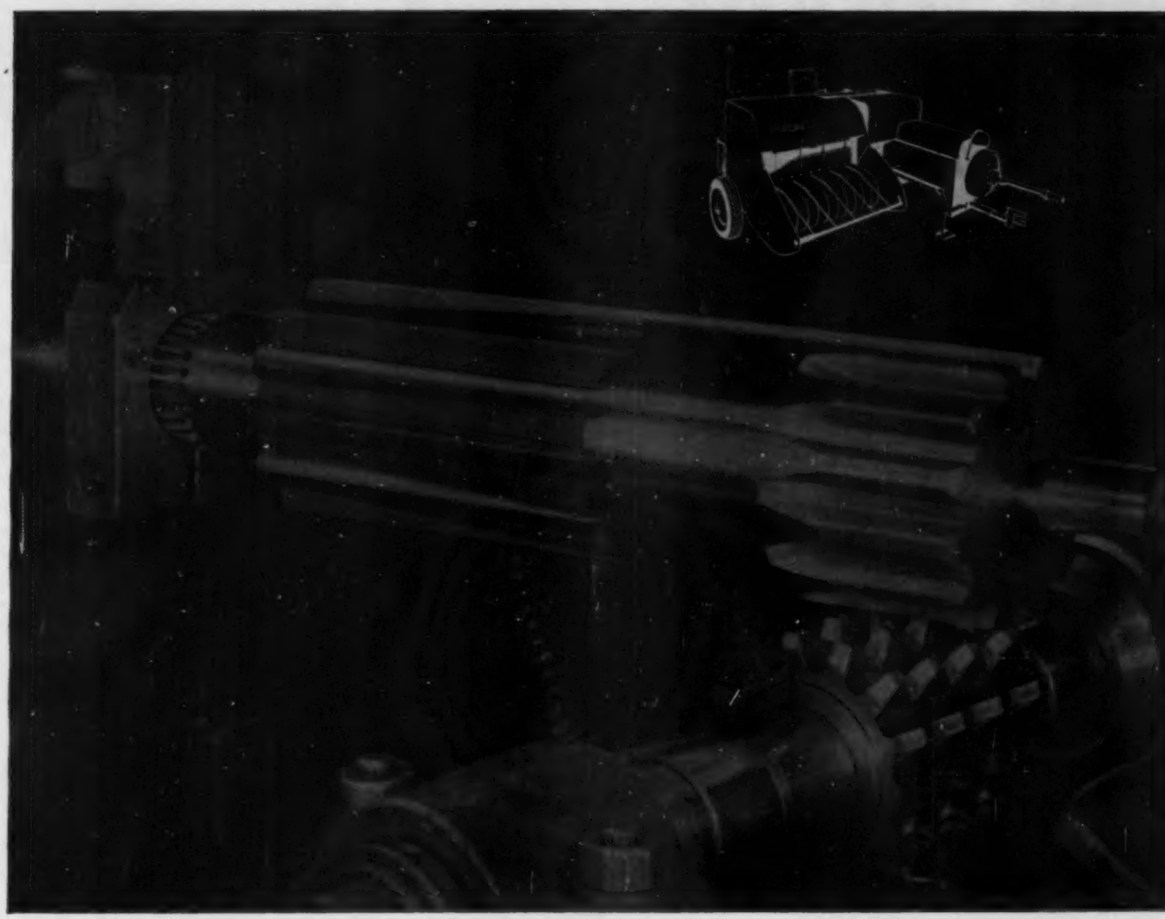
Weighing approximately 1600 lb ready to run, CERV-I is built around an extremely stiff frame of chrome-molybdenum steel tubing welded into a truss-like structure that weighs only 125 lb. Length of the car is 172 in.; wheelbase is 96 in., and width is 52 in.

Power for CERV-I is delivered by a special lightweight version of Chevy's 283-cubic inch V-8 that develops 350 hp, weighs 350 lb. High power-to-weight ratio was achieved by using an aluminum cylinder block, cylinder heads, water pump, starter-motor body, flywheel, and clutch pressure plate. Magnesium was used for clutch housing and fuel-injection manifold. No bore liners are used; pistons run directly on specially treated aluminum bores. Power transmission to the wheels is through a conventional four-speed gearbox; individual axle shafts with universal joints on each end (total of four U-joints) completes the drive train.

Other engine features include: Special fuel-injection unit, individually tuned exhaust pipes, no mufflers, no cooling fan, aluminum radiator and two oil-cooler radiators.



Rubber fuel tanks, mounted on either side of the car and straddling the cg, minimize effect of fuel level on weight distribution. Coil-spring suspension is used all around; rear suspension is designed to permit variation in camber and toe-in.



Oliver Corporation

cuts machining costs 40%

on main drive shaft for baler with STRESSPROOF STEEL BARS

"We get greatly improved machinability when we use Stressproof steel bars instead of 4140 alloy," says Mr. Carl H. Frailey, purchasing agent for Oliver at Shelbyville, Illinois. Here's how:

"33% Faster 'blanking out' on the tracer lathe."

"50% Less dressing of grinding wheels."

"$3,000 Savings on cutters . . . we now spline 40 pieces for every cutter setting, compared with 12 pieces using 4140. This means only two $500 cutters a season instead of two a month."

Write for a sample test bar and see how Stressproof can reduce your cost per part. Get strength (100,000 psi yield) without heat treating, plus . . . wearability . . . minimum warpage . . . fast machining.

Use this coupon to ask for Helpful Data Bulletins

- ☐ No. 15, Stressproof

Need still higher strength?...ask for one of the following bulletins:

- ☐ No. 10, Fatigue-proof® bars (125,000 psi yield)
- ☐ No. 22, "e.t.d.®" 150 alloy steel bars (130,000 psi yield)
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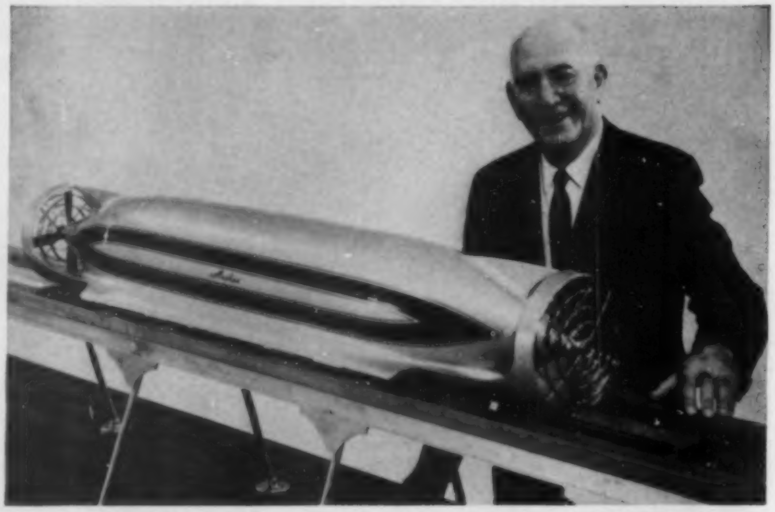
Ford Sees Levicar Challenge to Aircraft



Scale model of Ford's Levicar was built for demonstration purposes. Full-size vehicle able to carry 200 passengers would be propelled by twin 650-hp turboprop engines, and it would be buoyed above the track by two 500-hp turbocompressors, according to company spokesmen.

DEARBORN, MICH.—To further demonstrate the merits of the Levicar system of intercity transportation (MD, May 25, 1961, p. 12), Ford Motor Co. has built an operating scale-model of a 200-passenger vehicle. Named "Aeolus" after the Greek god having dominion over the winds, the model slides on a film of air a fraction of an inch above special rails. The full-size Aeolus would travel between cities at speeds up to 500 mph.

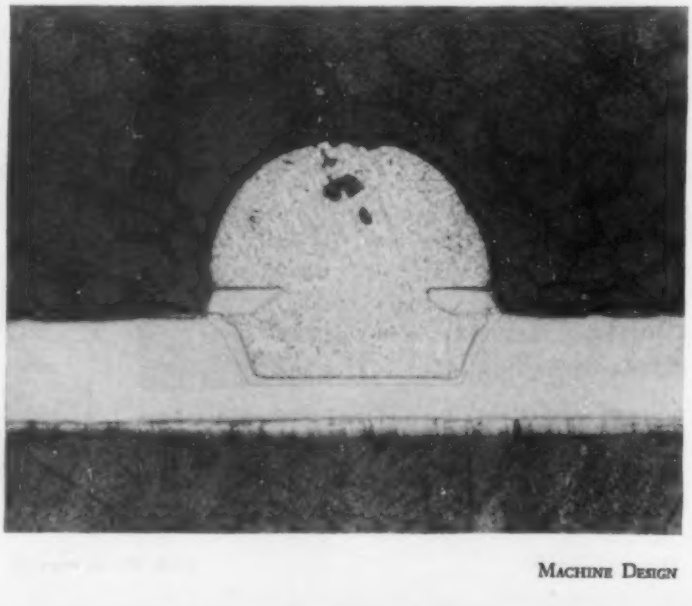
Calculations show that a 76,000-lb vehicle would carry 200 passengers, reports Dr. Andrew A. Kucher, vice president, engineering and research. "It would require 17 hp to lift each ton, and an additional 8 hp per ton for guidance."

Because lifting-power needs remain constant, the Levicar has some decided advantages over aircraft, Dr. Kucher points out. Wings designed for aircraft by the best established practice have a lift-drag ratio of 20. Ignoring drag imposed by the aircraft fuselage, 53 hp per ton are required for lift at 200 mph, 80 hp at 300 mph. In contrast, the total requirement to free the Levicar from the ground and guide it is 25 hp per ton at any speed.

"An additional 160 hp will be necessary to move the full-scale Aeolus 100 mph. Propulsion requirements increase by the cube of velocity, however, and 1300 hp would be needed for 200 mph, 4320 hp for 300 mph."

The revolutionary aspect of the projected Levicar system is that the vehicles will not ride on traditional wheels, but on air. About 200 mph can be considered the practical maximum speed for wheeled vehicles, Dr. Kucher claims. Right now, cars entered in the annual Indianapolis "500" attain about 185 mph on the straightaways, but require at least one pit stop during the race for new tires. Steel wheels also are incapable of sustained speeds above 200 mph. High-speed wheel problems include vibration, loss of traction, and loss of directional control.

Doping Efficiency Boosted For Aluminum-Boron Alloy



An improved aluminum-boron alloy with superior doping efficiencies may replace conventional aluminum, aluminum-gallium, and aluminum-silicon semiconductor materials, according to the developer, Alloys Unlimited Inc., Long Island City, N. Y. Containing up to 1 per cent boron, it can be used in any silicon device where p-plus ohmic contact or pn-junction formation in n-type silicon is necessary (microphotograph shows p-type silicon regrowth when the alloy is fused on n-type silicon, right). Now being offered to the semiconductor industry for laboratory tests, samples of the material can be obtained in foils, washers, and discs formed to conventionally tight tolerances. The company also expects to have spheres available in the near future.

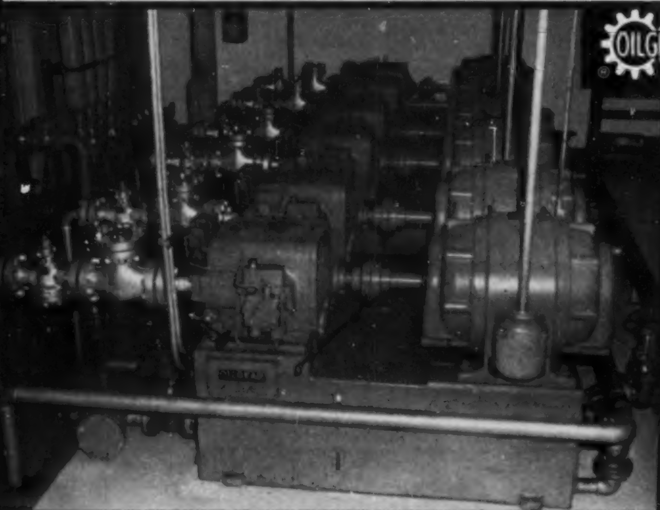
... Fluid Power news

Report No. 12,201 — From Oilgear *Application-Engineering* Files

How OILGEAR Pump and Control Systems help improve quality — speed production for the world's largest producer of high-fidelity phonograph records.

PROBLEM: High-speed production of high-quality vinyl (PVC), monaural and stereophonic phonograph records. Maintain weight tolerance within 5 grams . . . extend molding die life to increase the total of perfect "pressings" per mold . . . reduce cracks and scratches — imperfections as small as one-millionth of an inch can impair high-fidelity stereophonic reproduction. Pulsations, uncontrolled peak pressures, cylinder ruptures, and high percentage of production "pressing rejects" experienced with other pump systems could not be tolerated.

PUMP AND CONTROL SYSTEM REQUIREMENTS: 1. Cushioned, pulsationless *Fluid Power* at controlled pressures up to 3000 psi, for operating a battery of 90 record molding presses from a central supply system, and systems for self-contained, automatic, record molding presses. 2. Consistent, repetitive pressure build-up within 1/10 of a second. 3. Constant holding pressure without excessive heating, power loss, and no fluctuations. 4. Clean, heavy-duty, dependable, continuous pump operation — 24-hours-per-day, 5 to 7 days-per-week.



OILGEAR Application-Engineered Pump and Control System for "Hi-Fi" Phonograph Record Molding Presses.

ABOVE LEFT: The "Pump Room" — central **Fluid Power** Supply System for operation of a battery of 90 record molding presses in one of this company's four domestic plants . . . all pipes are color-coded, and the green painted floor is always spotless. **ABOVE RIGHT:** One of three Oilgear **Application-Engineered** System **"Power-Paks"** completely assembled for this application — ready for fast, simple installation.

SOLUTION: Central Oilgear *Application-Engineered Fluid Power* multiple, heavy-duty Pump and Control System for operating the battery of 90 vertical record molding presses. This system consists of six Oilgear "DP-6025" Heavy-Duty, Variable Delivery Pumps with automatic, integral pressure unloading, power-saving controls — mounted on three, separate, 400-gallon, reservoir bases. Either two, four, or six Pumps can economically supply the *Fluid Power* as required for production demands. Each molder easily operates a vinyl pre-plasticizer-feeder, two record molding presses, and a flash trimmer. Operator loads press #1 with a record label, a pre-plasticized, coiled "bisquit" of vinyl of predetermined weight, a second record label, and depresses control button to start press cycle. A molded and cured record from press #2 is unloaded, and placed on a flash trimmer. Press #2 is then "reloaded" with labels and pre-plasticized, coiled "bisquit" while press #1 is forming and curing a record. Each press can produce one 12" record every 40-seconds. Individual, integral, Oilgear heavy-duty Pump and Control Systems are also used extensively on self-contained, high-speed, completely automatic record molding presses to provide; Rapid traverse clamping — smooth slow-down for clamp closing — injection of preplasticized vinyl — center-hole punching — return of injection ram — change of final clamping pressure for curing — opening of clamping ram — stripping of record from mold, and removal to conveyor — and start next cycle . . . an example of "automatic production" at its best.

Built for continuous, long life at full-rated load, Oilgear heavy-duty Pumps keep record molding presses humming at peak capacity in this user's plants in the United States, Canada, Mexico, and affiliates overseas — that combined produce 80% of all phonograph records. Users and press manufacturers alike, report — *"For the lowest-cost-per-year — with the most advanced, precision controls known to industry . . . it's Oilgear — the pace-setting pioneer!*

For practical solutions to YOUR rotary or linear drive and control problems, call the factory-trained Oilgear Application-Engineer in your vicinity. Or write, stating your specific requirements, directly to . . .

THE OILGEAR COMPANY

Application-Engineered "Any-Speed" Drive and Control Systems

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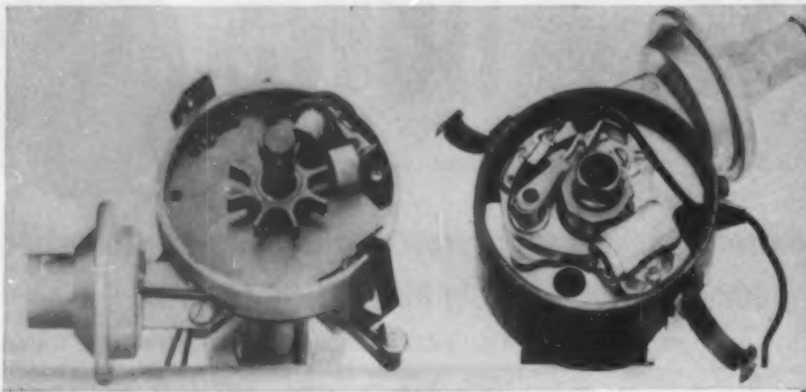


Pulse Generator Key to Pointless Ignition

Magnetic pulse generator (above, far left) is claimed to be much more reliable than the conventional distributor shown next to it. Rotating at high rpm, the toothed wheel never touches the magnet. Since there is no wear, the device needs no adjusting. Other parts in the new electronic ignition system include a distributor cap, an ignition coil, and a transistorized pulse amplifier (above). First cost is slightly higher than that of a conventional system, but by the time the car owner has changed points once he will have made up the difference.

CHICAGO—An electronic ignition system for cars and trucks, developed by Motorola, Inc., completely eliminates breaker points and condenser in the distributor. It replaces them with a small magnetic pick-up system that will reportedly last the life of the automobile.

Already being tested by several automotive manufacturers, the new ignition consists of a magnetic pulse generator (a small, spoked or toothed wheel that rotates past a tiny magnet without touching it), a transistorized pulse amplifier, and an ignition coil. According to the company, it has several major advantages:

- Wear is eliminated (wheel and magnet do not touch); distributor adjustments will not be necessary.
- Pulse, or dwell, time is constant at all engine speeds.
- Misfiring due to high-speed point chatter is eliminated.
- Spark stays hot, even at high speeds.
- Battery drain is very low.

The type of breaker-point ignition in use on automobiles and trucks today dates back some 40 years, points out Elmer H. Wavering, Motorola executive vice president. In contrast, the new system leans heavily on up-to-date technology; it was not possible before the advent of transistors.

Topics

Conversing from Kilimanjaro may be the next convenience offered members of African safaris. British engineers have finished tests prior to the installation of a vhf radio-telephone link between the 18,635-ft peak of Mt. Kilimanjaro and the coastal city of Dar es Salaam, Tanganyika.

• • •

Safety of the Liberty Bell will be assured, partly through the effort of engineers employed by the Franklin Institute, Philadelphia. It has been determined, by the Committee for the Preservation of the Liberty Bell, that the framework needs strengthening. The bell has been displayed in Independence Hall for over a century, most of the time hanging from the original wooden yoke which was built for use in the State House in 1853. In 1929 a steel plate was placed inside the yoke. This plate will now be replaced by a T-shaped steel beam strong enough to bear twice the weight of the 2080-lb bell. A new steel platform will also replace the present pedestal on which the bell and its side frames rest. The problem of what to do with the bell while its supports are being reinforced will be solved by lowering it into a concrete "cushion." Poured into a circular steel trough, the wet concrete will set up to fit the rim of the bell, and thus prevent its crack from spreading. Our symbol of liberty will be displayed on the cushion from mid-January until March, when the strengthened supports will be ready.

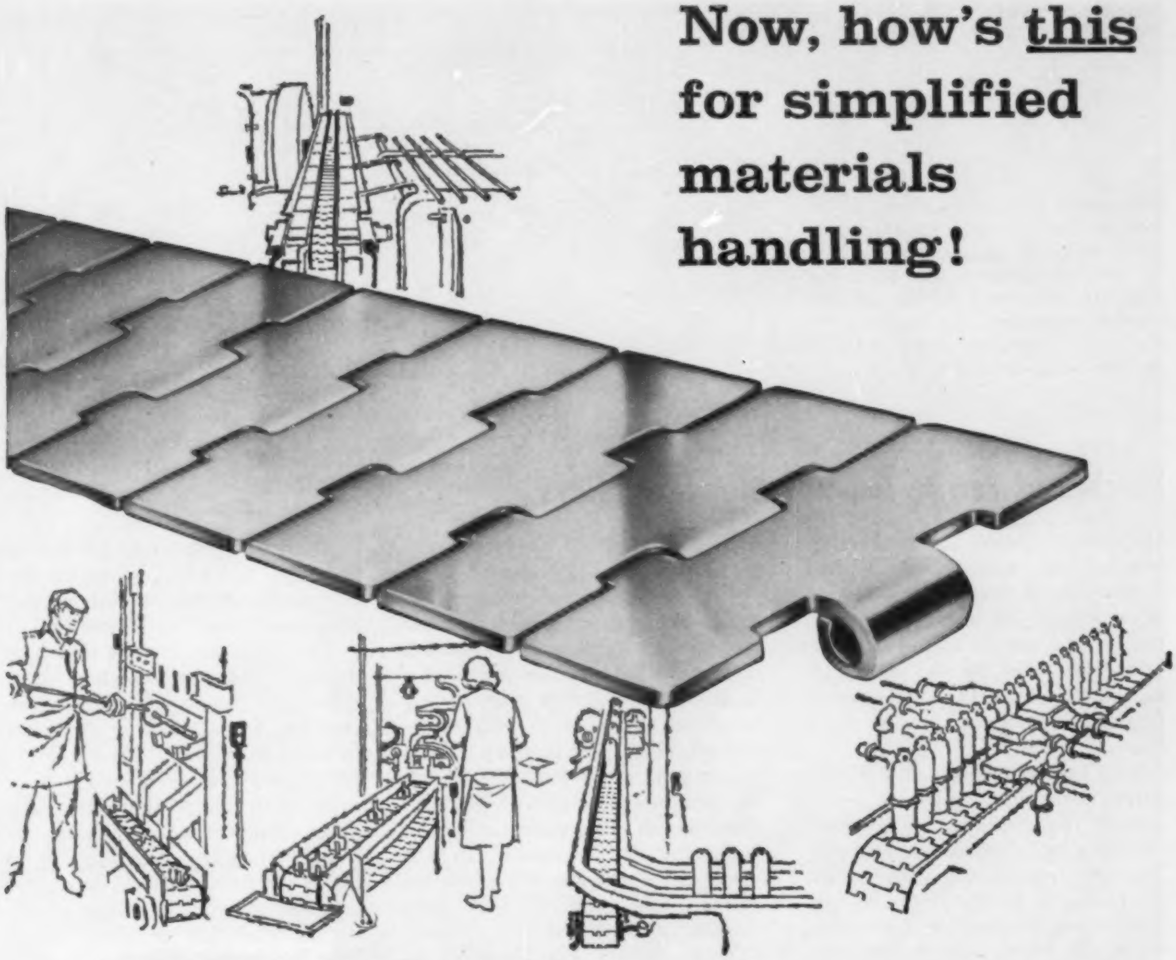
• • •

The better to shoot: A number of hearing aids were purchased this fall by people whose ears work perfectly well for everyday listening. They are hunters who are taking advantage of the instruments' amplifying powers to assist them in stalking game. Not to be outfoxed, game wardens are tuning in their own new hearing aids to listen for illegal shooting.

• • •

A rest cure on the moon may be prescribed by future physicians for patients who would benefit from the reduced pull of gravity. This possibility is foreseen by the Life Sciences Div. of Aerojet-General Corp., which suggests that an orbiting medical laboratory could offer opportunities to study the heart—to see how it would function without having to contend with gravity—as well as certain aspects of surgery and disease. Cosmic radiation might also be put to good use, say A-G scientists.

Now, how's this for simplified materials handling!



REX TableTop® Chain

If you are handling anything from small, fragile parts to hot abrasive forgings, Rex TableTop may very well be just the thing for you, too. It's simple; it's versatile; it's economical!

It quickly became the leading "tops" chain in the food, bottling and canning industries. Now Rex TableTop is bringing new, cost-cutting service to a wide variety of industrial applications.

If you want long, trouble-free service life without lubrication or if conditions are abrasive, hot, cold, wet or corrosive, Rex TableTop is ideal—for Rex TableTop is available in a variety of materials: carbon steel, stainless steel, or new Delrin (a new acetal resin by DuPont), and in five widths from 3¼" to 7½".

REX TABLETOP:—provides a flat, continuous plane carrying surface. Rex close-hinge design practically eliminates the gap between plates—smallest, tallest parts ride tip-free, snag-free—provides top economy! Simple, 2-piece construction—platform link and pin—means low initial cost, easy installation and lowest possible maintenance expense.

A TYPE FOR EVERY REQUIREMENT

REX TABLETOP OF CARBON STEEL—heat-treated for maximum strength and longest wear life—handles hot, abrasive forgings and heavy parts or boxes easily.

REX TABLETOP OF STAINLESS STEEL—provides strength and wear life of steel, yet resists corrosion.

REX TABLETOP OF DELRIN—stays strong, wet or dry; requires no lubrication; resists corrosion from most acids, alkalies or brine solutions; resists abrasion, will not scratch or mar the most delicate items.

For complete information on all Rex TableTop Chains, write CHAIN Belt Company, **4643** W. Greenfield Ave., Milwaukee 1, Wis. In Canada: Rex Chainbelt (Canada) Ltd., Toronto and Montreal.

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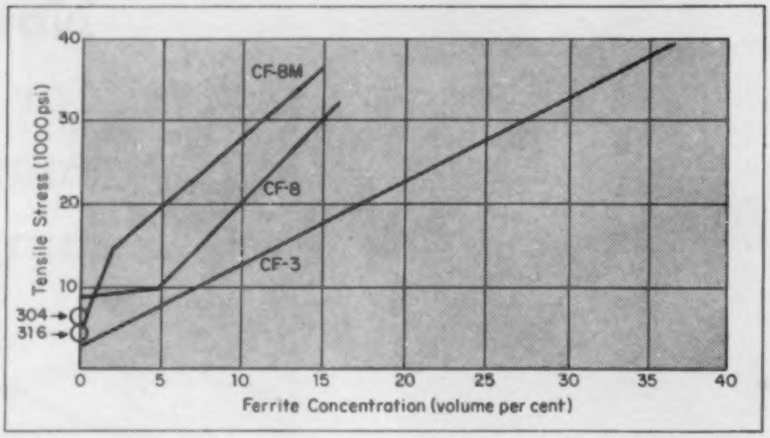


Cast alloys CF-3, CF-8, and CF-8M increase their resistance to stress-corrosion cracking as ferrite content is built up. Wrought stainless steel types 304 and 316 with zero ferrite are also plotted. Samples were exposed for 8 hr to condensate from 875-ppm chloride water heated to 400 F.

Pinches of Ferrite Improve Stainless Alloys

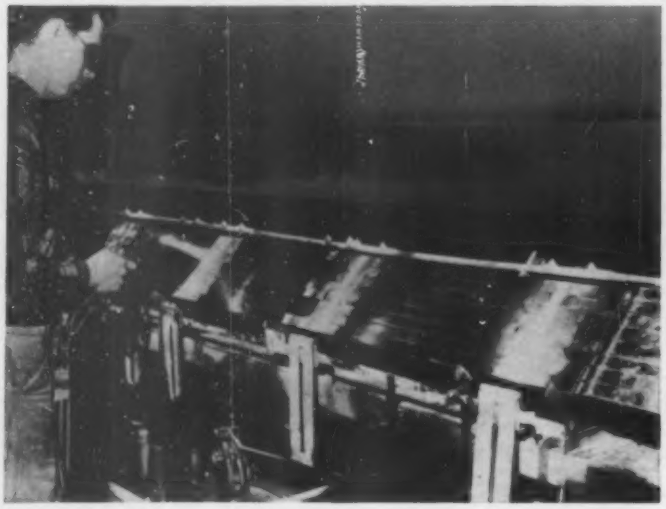
COLUMBUS, OHIO—Users of chromium-nickel stainless steels had better discard their magnets—that is, if they're assuming that magnetism is a test of corrosion resistance—according to the results of an Alloy Casting Institute research program just completed at Ohio State University.

The rather widespread but mistaken notion that corrosion resistance of 18-8 stainless steel is related to its magnetic properties originated because the composition that is best for rolling is wholly austenitic, and thus wrought stainless is nonmagnetic. However, the compositions of wrought 18-8 stainless selected for hot-working properties just happen to be nonmagnetic; they do not have greater corrosion resistance than 18-8 stainless alloys containing ferrite.

The ACI-sponsored research has shown that an appreciable amount of ferrite in stainless alloys (which make them magnetic) is quite beneficial since the ferrite gives greatly improved resistance to stress-corrosion cracking. The presence of even minor amounts of ferrite in the alloy structure dramatically improves resistance to stress-corrosion attack. Increasing ferrite content in the three cast stainless alloys tested (CF-3, CF-8 and CF-8M) gave startling increases in stress corrosion resistance. For instance, increasing ferrite content of the type CF-8 alloy from 5 to 16 per cent raises the stress required for cracking from 10,000 to 32,000 psi; similarly there is a ten-fold increase in resistance to cracking when the ferrite content of the low carbon CF-3 alloy goes from 4 to 39 per cent.

The graph also reveals that both wrought and cast stainless alloys have poor resistance to corrosion cracking when there is no ferrite in the compositions. When wrought 18-8 stainless grades are to be used in an environment that might produce stress corrosion cracking, introduction of ferrite in the alloy is not a practical remedy, since the compositions must be wholly austenitic to avoid hot working defects. This "no ferrite" limitation does not apply to cast alloys—thus, high alloy foundries can adjust the composition limits to meet a wide range of stress corrosion conditions.

Silver Coating Sprayed on Aluminum



By spraying powder through a flame, engineers at Powder Weld Inc., Brooklyn, N. Y., have developed the first practical method of applying a hot-melt silver surface to aluminum. The silver powder is carried in a shield gas (mixture of hydrogen and nitrogen) that protects it from atmospheric contamination and allows it to form an anodic bond with the aluminum, eliminating any oxide layer between the two. Cost of the equipment is about 1/25th that of standard electroplating tank equipment, according to PWI, and the silver can be applied selectively to precisely those electrical-contact areas where it is needed. This results in significant savings in silver. Portable equipment of this type has been thoroughly tested and has proved its worth in the manufacture of aluminum bus bars and switch-gear components. In addition, the technique will also be useful in applications where aluminum must be protected against oxidation, reports the company.

It's easy as 1–2–3 with...

TORRINGTON NEEDLE BEARINGS FEATURE:

- ☐ Unique unit construction
- ☐ Full complement of retained rollers
- ☐ Unequalled radial-load capacity
- ☐ Low coefficient of starting and running friction
- ☐ Low unit cost
- ☐ Long service life
- ☐ Compactness and light weight
- ☐ Run directly on hardened shafts
- ☐ Permit use of larger and stiffer shafts

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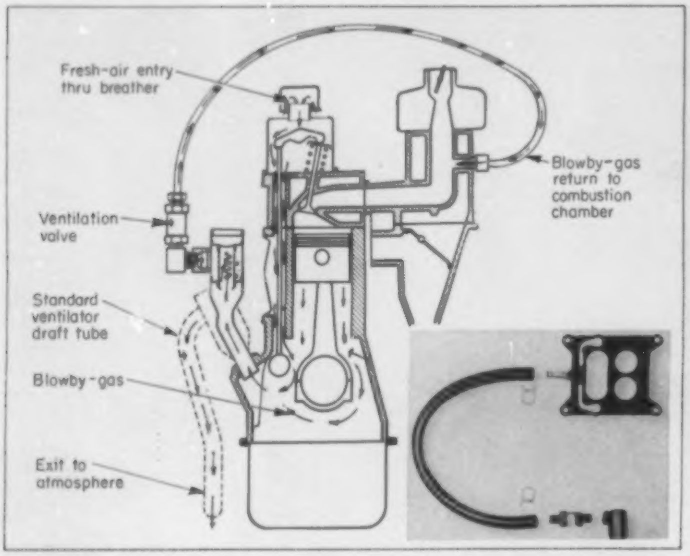
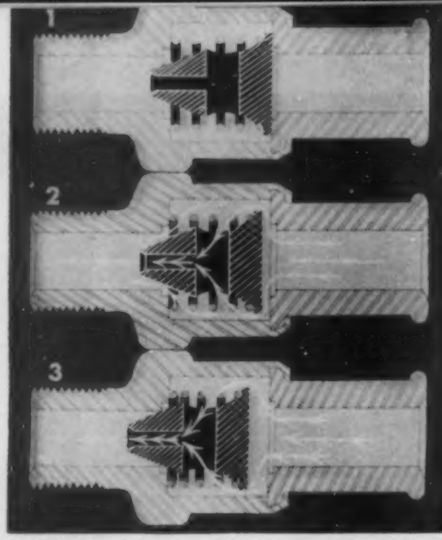
Circle 210 on Page 19





Ventilation valve regulates flow of blowby gas: 1. At zero vacuum (before engine start), valve closes to prevent crankcase explosion that might occur from backfire. 2. Maximum flow at high-speed. 3. Minimum flow occurs at high intake manifold vacuum when valve keeps air-fuel ratio from becoming too lean during idle and low speed. This action also prevents drawing of crankcase oil into manifold.

Blowby Will Be Standard on All '63 Cars

CLEVELAND—Positive crankcase ventilation systems will be standard equipment on all 1963 cars, according to a recent decision of the Automobile Manufacturer's Association. The so-called "blowby devices" eliminate approximately 30 per cent of unburned hydrocarbon emissions from gasoline-powered vehicles.

Significance of crankcase fumes in air pollution was discovered by engineers at General Motor's Research Laboratories two years ago. Since that time, the Company's AC Spark Plug Div. has devoted an estimated 40,000 engineering hours to the testing of more than 100 blowby systems, and is currently the sole industry source.

AC's system (pictures) consists of an adapter to replace the standard crankcase draft tube, a ventilation valve, tubing and clamps, and an adapter plate which fits under the carburetor. Crankcase fumes circulate through the system and are returned to the engine where they are burned.

Current price of the system: From \$4.50 to \$6.50.

Inorganic-Membrane Fuel Cell Generates High Power

Fuel cell the size of a quarter operates at 90 per cent efficiency, generates slightly less than 1 v, and produces a current density of 100 amp per sq ft. Organic-membrane cells produce about 35 amp per sq ft.

CHICAGO—First fuel cell to use an inorganic ion-exchange membrane operates more efficiently and at higher temperatures than do the organic-membrane types. Developed by Armour Research Foundation, Illinois Institute of Technology, it attains high power at 100 C. Performance of organic cells falls off rapidly above 70 C.

Fueled with hydrogen and oxygen, the inorganic cell has an unusually high energy-to-weight ratio. Because the inorganic materials do not require water—organics need liquids to maintain pliancy of the membrane—they are inherently lighter.

The ARF cells, about the size of a quarter, produce 0.95 v (open circuit); currents are as high as 100 amp per sq ft. When a number of the wafer-shaped cells are arranged in series, sufficient voltage can be derived to supply power for satellite communications, for telemetry devices in space, and for support equipment to be used during manned landings on the planets, according to Armour spokesmen.

Lavish Fringe Benefits Thrust on Engineers Abroad

NEW YORK—Engineers in developed countries abroad enjoy fringe benefits unknown to most in the United States, and these sometimes add 40 per cent to payroll costs. So said Merrit L. Kastens, manager, Project Planning & Analysis Dept., Union Carbide International Co., at the 54th National Meeting of the American Institute of Chemical Engineers.

"One of the major overseas fringe benefits which is often not quite properly considered in calculating base wage rates is time paid for and not worked." Average paid vacation for regular production workers in the developed foreign countries is "about three weeks, often fixed by law." For management it is four weeks. For senior management it often is six and sometimes eight weeks. Paid holidays range from 10 to 18 days per year. Time off given in most foreign countries in addition to holidays and vacation "has no counterpart in the U. S."

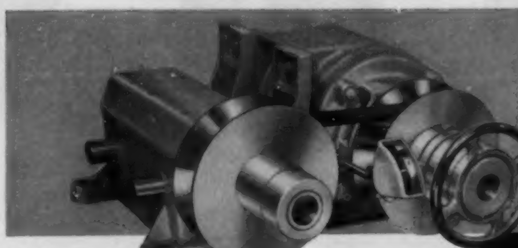
As to bonuses: The "Thirteenth Month" is becoming quite common outside the U. S., and it is just what it sounds like—a year-end bonus equal to a month's pay. In addition, summer bonuses, usually paid at the beginning of a vacation, are becoming increasingly common. Although they are usually smaller, in some case they do amount to a "Fourteenth Month."

In assessing over-all manpower costs, "the hardest factor to handle is what might be called custom":

• The ratio of professional to supporting personnel in Japanese research "may go to ten-to-one."

• In Germany, the board of directors most normally includes a union representative who gets a handsome salary and a Mercedes with a driver—but he does very little more than come to board meetings.

German law prohibits waivers of patent rights, and employers must buy them. In France and the United Kingdom it is hard and very costly to discharge a person. In Japan, it is unthinkable, except for a criminal act or impending bankruptcy. Hence, payrolls may be loaded for years with incompetents or superfluous persons.



NOW...

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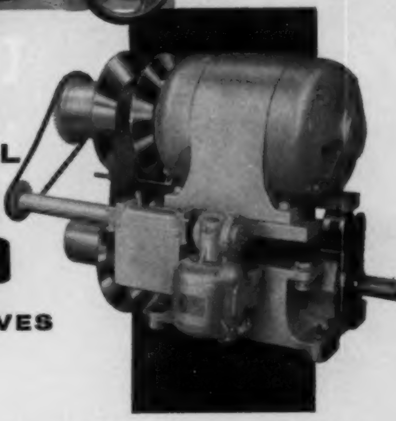
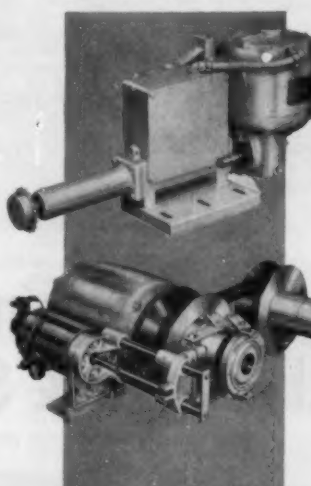
VARIABLE SPEED DRIVES



Here are both horizontal and vertical variable speed drives. Each is an assembly of standard components—a motor, LEWELLEN Combination Pulleys, and the horizontal or vertical Countershaft.

The horizontal drive assembles either right hand or left hand. Both the horizontal and vertical drives mount at floor or ceiling.

Accessories may include the mechanical Indicator, or the Electric Tachometer and Electric Remote Control, as shown.



A bridge circuit controller dials all speed settings by equipping the Electric Control unit with a potentiometer.

Or, the Pneumatic Regulator automates the operation by connecting with process instruments.

Here are accessories for readily using the flexibility of variable speeds — for using LEWELLEN Variable Speed Drives as you choose.

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LEWELLEN

Manufacturing Company, Columbus, Indiana

Distributors in all Industrial Areas

Circle 211 on Page 19

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NEW PRODUCT IDEAS in the works? A suggestion — when you start your power equipment design layouts, use the detailed Engine Specifications available from Briggs & Stratton. Also available is Briggs & Stratton's Consulting Engineering Service with almost four decades of small engine power application experience. Write or phone Hugh S. Brown, Engineering Vice President, Briggs & Stratton Corp., Milwaukee 1, Wisconsin. (Phone LOcust 2-5000)

Circle 212 on Page 19

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HELPFUL LITERATURE

Descriptions of items start on Page 166. Starred items are from Dec. 7 issue.

Electrical, Electronic

501 **Linear, Rotary Solenoids.** 6 pp. Western Div., IMC Magnetics Corp.

502 **Electrical Tape.** 8 pp. Tape Div., Plymouth Rubber Co. Inc.

504 **Silicon PNPN Devices.** 8 pp. Solid State Products Inc.

508 **Contact Relays.** 8 pp. Potter & Brumfield Div., American Machine & Foundry Co.

512 **Selenium Photovoltaic Cells.** 4 pp. Westron Instruments Div., Daystrom Inc.

516 **Miniature Solder Connectors.** 24 pp. Burndy Corp.

524 **Fractional-Horsepower Motors.** 4 pp. Carter Motor Co.

526 **Miniature Connectors.** 10 pp. Consolidated Electrodynamics Corp.

529 **Snap-Action Switch.** 4 pp. Electrical Contacts & Specialties Div., Fansteel Metallurgical Corp.

530 **Industrial Thermocouples.** 56 pp. Barber-Colman Co.

532 **Hermetically Sealed Relays.** 20 pp. General Electric Co.

535 **Tantalum Capacitors.** 4 pp. Ohmite Mfg. Co.

536 **Pneumatic Timing Relay.** 4 pp. Cutler-Hammer Inc.

538 **Rotating Components.** 8 pp. Magnetics Div., March Dynamics Inc.

539 **Magnetic Starter.** 4 pp. Furnas Electric Co.

542 **Wire and Cable.** 4 pp. L. Frank Markel & Sons.

545 **Rotary Solenoids.** 32 pp. Ledex Inc.

579 **Monoplanar Switching.*** Two bulletins discuss advantages, describe Uniplane switch kits. Bulletins 6130 and 6131, 8 pp. Ucinite Co., Div., United-Carr Fastener Corp.

580 **Electromechanical Components.*** Specifications for components, lists applications. Catalog 100, 140 pp. Siamco Div., Tech-Ohm Electronics Inc.

581 **Bimetal Thermometers.*** Industrial, laboratory, Navy, pocket types. Catalog 09-100, 16 pp. Weston Instruments Div., Daystrom Inc.

582 **Industrial Engine.*** Covers valve-in-head, air-cooled, 60-hp unit. Bulletin S-282, 4 pp. Wisconsin Motor Corp.

583 **Polarized Relays.*** Sensitive, small, high-speed units. Catalog F, 6 pp. Magnetic Devices Inc.

584 **Miniature Connectors.*** Hyfen Bantam units that conform to MIL-C-26482. Catalog BHB, 32 pp. Burndy Corp.

585 **Silicon Rectifiers.*** Covers standard rectifiers and rectifier stacks. 44 pp. Rectifier-Capacitor Div., Fansteel Metallurgical Corp.

586 **Motors, Generators, Synchros.*** Theory, performance, construction, application, testing. 60 pp. Kearfott Div., General Precision Inc.

587 **Slip-Ring Assemblies.*** Scope; application; specifications for various types. Catalog SR-1, 16 pp. Superior Carbon Products Inc.

588 **Limit Switches.*** Describes Type L oiltight units. Catalog LJ-48, 20 pp. Cutler-Hammer Inc.

589 **Flush Pushbuttons.*** Oil-Tite flush units for use in standard or custom stations. Booklet B-7356, 8 pp. Westinghouse Electric Corp.

590 **Polarizing Systems.*** Polarite system for accurate insertion of modular circuit-board assemblies. Bulletin 6120, Ucinite Co., Div., United-Carr Fastener Corp.

Hydraulic, Pneumatic

503 **Braided, Twisted Packings.** 20 pp. Garlock Inc.

510 **Fluid-Power Products.** 12 pp. Weatherhead Co.

514 **Filter Assemblies.** 34 pp. Aircraft Porous Media Inc., Subsidiary, Pall Corp.

515 **Hydraulic Cylinders.** 12 pp. Rivett Lathe & Grinder Inc.

520 **Hydraulic System.** 4 pp. Dynex Inc.

523 **Flexible Pressure Hose.** 8 pp. Polymer Corp.

537 **Valve Operators.** Ledeen Inc.

540 **Vacuum Pumps.** 8 pp. Schutte & Koerting Co.

543 **Hydraulic Cylinders.** 20 pp. Denison Engineering Div., American Brake Shoe Co.

544 **Bendable Tubing.** 4 pp. Flexaust Co., Div. Callahan Mining Corp.

591 **Control Valves.*** Discusses two primary types of control-valve design. Booklet SBV-1, 8 pp. Conoflow Corp.

592 **Pressure Hose.*** For loading, unloading, and conveying steam, oil, tar, asphalt. Bulletin 15-E, 6 pp. Atlantic Metal Hose Co. Inc.

593 **Fluid Coupling.*** VariDraulic drive, a controllable hydrostatic fluid coupling. 18 pp. Hydraulics Inc.

594 **Machined Bellows.*** Uses in missile, nuclear, and chemical industries. Bulletin 1401, 4 pp. Hydrodyne Corp.

595 **Metallic Gaskets.*** Spirotallic, metal-jacketed, flat-metal, corrugated, round cross-section, heavy cross-section units. Booklet PK 152A, 28 pp. Packing & Friction Materials Div., Johns-Manville Co.

596 **Hand Pumps.*** Describes 12 fluid-power units. Catalog 100-C3, 8 pp. Commercial Shearing & Stamping Co.

597 **Plastic-Clad Pipe.*** Polyether pipe for high-order corrosion protection. Bulletin BR 13, 8 pp. Polymer Corp.

598 **High-Pressure Flowmeter.*** New 2-in. unit for liquid and gas applications. Sheet CM-49, 2 pp. Rotron Controls, Div., Rotron Mfg. Co. Inc.

599 **Water Pump.*** Model W vane-type pump for drink-vending machines, carbonators. Catalog Section 112, 4 pp. Tuthill Pump Co.

600 **Pressure Indicators.*** Covers six Deltadyne pressure and differential-pressure indicators. 8 pp. Pall Corp.

Mechanical Equipment

507 **Speed Reducer.** 44 pp. Hewitt-Robins.

511 **Standard Levers, Rocker Arms.** 8 pp. Stelron Cam Co.

518 **Couplings, Clutches.** 4 pp. Odin Corp.

601 **Ball Radial Bearings.*** Specifications on 90 sizes of Reali-Slim CP bearings. Bulletin S-141, 4 pp. Kaydon Engineering Corp.

602 **Bearing Data Sheet.*** Selection data on 143 miniature and instrument bearings. Sheet M-3, 2 pp. Barden Corp.

Assembly Components

505 **Fastener, Rivet Products.** 28 pp. Huck Mfg. Co.

521 **Stop Nuts.** 28 pp. Elastic Stop Nut Corp. of America.

603 **Sealing Washers and Fasteners.*** Two sheets cover Barclad washers and Barpad fasteners. 2 pp. L. J. Barwood Mfg. Co. Inc.

604 **Mechanical Counters.*** Covers 108 units for digital-readout applications. Form 227864, 8 pp. Veeder Root Inc.

605 **Lock Nuts.*** Lokon prevailing-torque nuts of heat-treated alloy steel. Form L-101, 4 pp. Lokon Div., Allen Mfg. Co.

606 **Stressed Panel Fasteners.*** Miniature and standard Zip-Loc units. Bulletin DF 166, 8 pp. Deutsch Fastener Corp.

Manufacturing Processes, Parts

607 **Cold Extrusion.*** Discusses advantages of the process. Booklet Adv. 1290, 8 pp. Republic Steel Corp.

Materials

506 **Plastic Shapes.** 64 pp. Cadillac Plastic & Chemical Co.

513 **Glass-Reinforced Plastics.** 4 pp. National Vulcanized Fibre Co.

517 **Mechanical Tubing.** 42 pp. Peterson Steels Inc.

525 **Perforated Metal.** 12 pp. National-Standard Co.

527 **Copper-Clad Laminates.** 6 pp. Synthane Corp.

531 **Industrial Plastics.** 16 pp. National Vulcanized Fibre Co.

533 **Precision Glass.** 4 pp. T. H. Garner Co.

541 **Teflon Fiber Felts.** 3 pp. American Felt Co.

608 **Epoxy Resins.*** Compares 17 Randac epoxy resins. 4 pp. Mitchell-Rand Mfg. Corp.

609 **Infrared Transmitting Materials.*** Reviews 15 materials, giving detailed properties data. 4 pp. Servo Corp. of America.

610 **Glass-Fiber-Reinforced Plastics.*** Lists fabrics and fibers, resins and catalysts, parting agents, pigments available. Catalog 2, 16 pp. Cadillac Plastic & Chemical Co.

611 **Protective Coatings.*** HumiSeal coatings for electronic applications. Chart C-503, 6 pp. Columbia Technical Corp.

612 **Industrial Wire Cloth.*** Engineering considerations for proper application. Catalog R-100, 28 pp. National-Standard Co.

613 **Laminated Phenolic Plastic.*** Specifications, properties of Ohmoid thermosetting phenolic plastic. 4 pp. Wilmington Fibre Specialty Co.

614 **Rod and Sheet.*** From copolystyrene rod to foam materials. 6 pp. Emerson & Cuming Inc.

HELPFUL LITERATURE (Cont.)

615 **Glass-Fiber Insulation.*** For industrial, military, consumer applications. Bulletin F101, 4 pp. Fibrous Glass Products Co., subsidiary of Pall Corp.

616 **Copper-Zirconium Alloy.*** Properties of Amzirc alloy; lists case histories. 36 pp. Amco Sales Div., American Metal Climax Inc.

617 **Nickel-Chrome-Iron.*** Use and specifications of ABK Metal. 4 pp. American Manganese Steel Div., American Brake Shoe Co.

Engineering Dept. Equipment

509 **Testing and Test Equipment.** 46 pp. Kearfott Div., General Precision Inc.

519 **AC and DC Voltmeters.** 28 pp. Trio Laboratories Inc.

522 **Thermocouple Selection.** Smith Thermotronics Inc.

528 **Tape Recorders, Perforators.** 8 pp. Tally Register Corp.

534 **Universal Marking System.** 6 pp. Esterbrook Pen Co.

618 **Servo Recorders.*** Models HR-80 and H-R 87 T-Y recorders. Houston Instrument Corp.

619 **Electrostatic Generators.*** Models with 50 to 600 kv output. 8 pp. Sames-USA.

620 **Level Recorder.*** Two reviews—"RMS Recording of Narrow Band Noise With a Level Recorder," "Effective Averaging Time of an RMS Level Recorder." 44 pp. B&K Instruments Inc.

621 **Data Processing.*** Systems applications involving tape-operated business machines. 32 pp. Friden Inc.

622 **Electromagnetic Flowmeter.*** Mag-Pipe unit which measures velocity of fluids. Bulletin 98418, 8 pp. Taylor Instrument Companies.

623 **DC Amplifier.*** Floating, differential unit for laboratory purposes or data-logging systems. Data Sheet 2096, 4 pp. Kin Tel Div., Cohu Electronics Inc.

624 **Self-Sticking Tapes.*** In transparent colors with glossy or matte surface. 4 pp. ACS Tapes Inc.

625 **Preprinted Drafting Symbols.*** Repetitive symbols and drawing details. 6 pp. Stanpat Co.

626 **Recorders, Controllers.*** Single and multipen, null-balance units. Bulletin GEA-6887 A, 12 pp. General Electric Co.

627 **Test Instruments.*** Expanded line of several types described. Bulletin CC-861, 4 pp. Borg-Warner Controls Div., Borg-Warner Corp.

Circle the item number for information on products advertised or described, literature offered, and copies of editorial articles.

NEW PARTS, MATERIALS, ENGINEERING EQUIPMENT

Descriptions start on Page 174.

Electrical, Electronic

549 **Toggle switch** for subminiature electronic devices. Micro-Miniature Controls Div., Otarion Listener Corp.

553 **Silicon rectifiers** for use in small spaces. Rectifier Components Dept., General Electric Co.

555 **Tantalum film circuits** in a wide variety of digital and linear types. Components Div., Texas Instruments Inc.

558 **Subminiature transistors** in four-lead, TO-18 cases. Semiconductor & Special Purpose Tube Div., Amperex Electronic Corp.

560 **Miniature connector** has crimp-type, removable contacts. Burndy Corp.

566 **Electric motors** in ratings from 1 to 7½ hp have short axial length. Doerr Electric Corp.

567 **Silicon transistors** in new TO-46 subminiature package. National Semiconductor Corp.

572 **Germanium mesa switch** is high-speed unit in TO-18 case. Transistor Products Div., Texas Instruments Inc.

Hydraulic, Pneumatic

547 **Fine metering valve** for 1/16-in. OD tubing. Nuclear Products Co.

552 **Arched seal** for shaft or cylinder walls. International Packings Corp.

556 **Washer-seals** for use with journal-type roller bearings. Corlett-Turner Co.

559 **Needle valve** in stainless steel or brass construction. Dragon Engineering Co. Inc.

561 **Liquid-level gages** for level variations from 1¾ to 5 in. Technical Development Co.

564 **Miniature fluid valve** senses temperature change of 1 deg. Pyrodyne Inc.

570 **Control valves** have flow rates to 16 cfm at 100 psi. Pneumatics Div., Bellows Valvair Inc., Div., IBEC.

Assembly Components

548 **Captive nut** for separation systems is shrouded type. Hi-Shear Corp.

Mechanical Equipment

546 **Miniature slip clutch** maintains constant slip torque. Precision Specialties Inc.

551 **Linkage joints** have positive stop for misalignment angle of 11 deg. Link-Age Corp.

554 **Idler pulleys** use oil-impregnated sleeve bearings. New Hampshire Industries Inc.

557 **Slip clutches** for potentiometer drives are ¼ to 5/16 in. long. Sentinel Standard.

562 **Flange-bearing assembly** for shaft sizes of 7/16, ½, ⅝ in. Randall Graphite Bearings Inc.

568 **Ball bearing** has rubber-metal seal. Fafnir Bearing Co.

Materials

550 **Vinyl-plastic coating** withstands heat to 250 F. A. L. Okun Co. Inc.

563 **Paper-base laminate** has good dimensional stability. Taylor Fibre Co.

565 **Miniature metal sections** for industrial use. Universal Molding Co.

571 **Nickel-base wire cloth** for 1800 F service. National-Standard Co.

Engineering Dept. Equipment

573 **Instrument chassis** for prototype development. Circuit Structures Lab.

574 **Drawing leads** have new degree stamping. Richard Best Pencil Co. Inc.

575 **Strain gages** for use in temperatures to 180 F. Metrix Inc.

576 **Direct-reading meter** for air velocity and temperature. Flow Corp.

577 **Vertical file** holds 100 drawings, plans, or prints of any size. Plan Hold Corp.

578 **Electronic copier** is completely automatic. Photorapid Corp.

EDITORIAL ARTICLES

Single copies of the following articles are available as long as the supply lasts. Starred items are from previous issues. See Page 198 for other available reprints. Editorial content of MACHINE DESIGN is indexed in the Applied Science Technology Index and the Engineering Index, both available in libraries. Microfilm copies are available from University Microfilms, 313 N. First St., Ann Arbor, Mich.

26-1 **Beans and Bullets Air Arm.** Turbine-powered helicopters and slow-flying aircraft will enhance Army's battlefield mobility by 1970. (4 pp.)

26-2 **Engineering or Management?** Tests to help an engineer decide whether he should stay put or try to get into management. (2 pp.)

26-3 **Vertically Suspended Shafts—Part 1.** Finding fundamental frequency of lateral vibration by analytical techniques. (8 pp.)

26-4 **Servo Systems for Velocity Control.** How to determine dynamic performance of electrohydraulic adjustable-speed drives. (8 pp.)

26-5 **Helical and Herringbone Gears.** Predicting strength capacity from new AGMA tooth-strength formula based on pitting resistance. (16 pp.)

26-6 **Thermal Stresses—Part 4.** Reducing thermal stresses by setting up residual stresses, avoiding stress concentrations, and providing surface protection. (6 pp.)

26-7 **Surface Coating for Beryllium Parts.** What coatings to specify for protection against corrosion and wear. (4 pp.)

26-8 **Cylindrical Pressure Vessels.** Charts to simplify design of pressure vessels for full vacuum inside and atmospheric pressure outside. (3 pp.)

26-9 **High-Temperature Seals—Abstract.** Properties, performance data for seal materials used in hot and corrosive conditions. (4 pp.)

25-2 **Product Innovations.*** Inside look at the factors which influence productivity. (5 pp.)

25-3 **Titanium Pressure Vessels.*** A state-of-the-art report. (6 pp.)

25-4 **Hydrostatic Transmissions.*** Engineering appraisal, including basic arrangements, evaluation techniques, performance prediction. (10 pp.)

25-7 **Basic Electronic Controls—Part 2.*** Indicators, recorders, and controllers. (24 pp.)

25-8 **Springs for Cam Followers.*** Short-cut design procedure which can be adapted for use with other spring-design problems. (6 pp.)

24-2 **Why New Products Fail.*** Common reasons for failure; how to avoid product-planning pitfalls. (4 pp.)

24-3 **Tolerance Standards.*** Minimizing notes on engineering drawings by setting up company tolerance standards. (5 pp.)

24-4 **Space Mechanisms.*** Finding velocities and accelerations of 30 mechanisms by fundamental graphic methods. (4 pp.)

24-6 **Designing Bevel Gears.*** New method for preventing bevel-gear failure caused by pitting. (8 pp.)

24-7 **Basic Electronic Controls—Part 1.*** Selection and application of electrical-output sensing devices. (26 pp.)

23-4 **Audible Signals.*** Relating basic properties of sound to the selection of sound-producing devices. (9 pp.)

23-11 **Beams with Nonuniform Stiffness.*** Two numerical methods for calculating deflection of cantilever beams with varying stiffness. (5 pp.)

22-7 **Keeping Bolted Joints Tight.*** Avoiding decoupling of vibrating joints held together by threaded fasteners. (4 pp.)

21-5 **Servovalves for Force Control.*** Using servovalves for accurate control of force in hydraulic system. (6 pp.)

20-3 **Gasket Loads.*** Four techniques for evaluating flange pressure factors to improve flanged-joint design. (7 pp.)

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26-6	25-8	22-7
26-7	24-2	21-5
26-8	24-3	20-3

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FIRST CLASS
Permit No. 36
CLEVELAND, OHIO

BUSINESS REPLY MAIL
No Postage Stamp Necessary if Mailed in the United States

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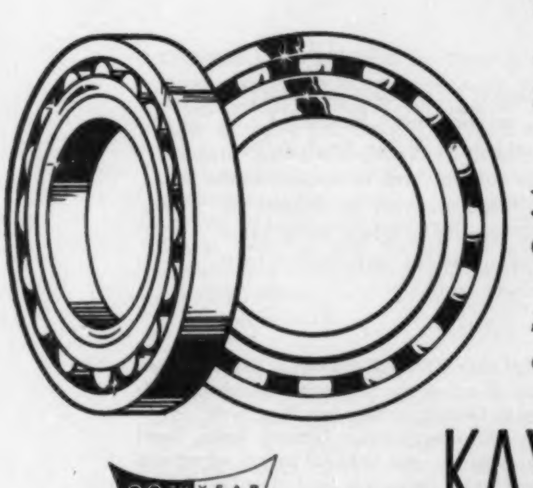
NEWS!

KAYDON NOW REDUCES PRICES ANOTHER 25% TO 42% FOR "CP" BALL RADIAL BEARINGS AVAILABLE "OFF-THE-SHELF"



Low prices are also being quoted on many other ball and roller bearings ...both standard (4" bore and larger) and special (2" bore and larger).

You can now save on many of your current and future purchases of these bearings.

Send your inquiry now! Write, wire, or call Kaydon, Muskegon, Michigan. Phone: PLaza 5-3741.

K-619

20TH YEAR 1941 KAYDON 1961

THE KAYDON ENGINEERING CORP.
• MUSKEGON, MICHIGAN

All types of ball and roller bearings — 2" inside diameter to 178" outside diameter . . . Taper Roller Roller Thrust • Roller Radial • Needle Roller • Ball Radial • Ball Thrust • Four-Point Contact Bearings

Circle 213 on Page 19

trends

aero/space

Tiros II Turns One

The second Tiros weather satellite—launched on Nov. 23, 1960 and expected to last about three months—was still going strong as it celebrated its first birthday. Recent photographs were almost as good as those it transmitted immediately after launch. In a year, Tiros II orbited the earth 5354 times, transmitting over 36,000 photographs and nearly 4 million feet of magnetic tape containing meteorological information. Among its outstanding deeds are the observation of a cyclone south of Australia and assistance (photographic) in predicting the end of a severe heat wave on the same continent.

First Supersonic Jet Transport May Have a French Accent

A 100-passenger Super-Caravelle, with cruising speed of 1500 mph and a 2800-mile range, is scheduled for commercial use in 1968. The French government and two aircraft companies—Sud-Aviation, manufacturer of the medium-range Caravelle, and Marcel-Dassault Aviation Co.—are working on the project. They plan flight tests in 1965. Meanwhile, the U. S. aircraft industry is wrestling with problems of building a 2000-mph jet with a 4000-mile (New York to Paris) range.

THE LARGEST SOLID-FUEL ROCKET test-firing at extremely low temperature was made by Lockheed Propulsion Co. (formerly Grand Central Rocket Co.). A 14-ft Spear rocket engine was fired at −50 F. Propellant was Polycarbutene-R, a type suitable for large rockets exposed to extreme temperatures and for boosting large manned vehicles to escape velocity.

STANDARDS FOR WIRE AND CABLE used in space vehicles are urged by Robert W. Campbell, Philadelphia Insulated Wire Co. Failures occur, says Mr. Campbell, because wire and cable engineering is often treated as an afterthought in the design procedure. He suggests forming an engineering facility—funded by the Defense Dept. and NASA—to develop standards.

engineering/personal

VA Goes to the U.K.

Value analysis was the topic under discussion at a recent gathering of top management from 20 major British corporations. Howard L. C. Leslie, co-founder and executive vice president of Value Analysis Inc., Schenectady, N. Y., came to explain the concept and to suggest how it could be utilized by British firms. Value analysis, as defined by Mr. Leslie's company, is a systematic and creative program using proven methods of operation to obtain the same or better performance from a product or service at a substantially lower cost.

HIGHER PAY for Government-employed engineers and scientists is being considered—at the White House level—to halt the exodus of top personnel. (In 1960, over 500 senior scientists, earning $13,700 a year or more, left for private industry, nonprofit research organizations, or universities.) The Government employs about 105,000 engineers and scientists at salaries ranging from $5000 to $19,000. Congress may be asked to raise the upper limit to $25,000 or $30,000.

DEMAND FOR ENGINEERS in October topped that of any of the 15 previous months, according to Deutsch & Shea Inc., New York. In the D&S Engineer/Scientist Demand Index, based on newspaper and technical-journal advertising, the October figure was 141.4 (July-Dec. 1960 = 100). Highest in the 16-month history of the index, the October figure is attributed partly to recruiting at the many technical conventions held then. However, advertising was up even in cities where there were no conventions.

Nonmagnetic Alloy Offers Unusual Properties

Nitinol, a new titanium and nickel alloy developed at the Naval Ordnance Laboratory, is destined for broad application because many of its characteristics are either unusual or unknown to other nonmagnetic materials. It resists corrosion, can be hardened to 62 Rockwell C, and tests up to 43 ft-lb impact strength. Although toughness increases as temperature decreases, Nitinol can be used at 1200 F. It has very high mechanical vibration capacity at room temperature. Potential uses range from mine sweepers to kitchen cutlery.

Manganese Steel Acquires Machinability

Machinable manganese steel having strength, toughness, and low magnetic permeability is announced by American Manganese Steel Div., American Brake Shoe Co. It contains 20 per cent manganese instead of the usual 13 per cent; yield strength is 35,000-45,000 (reduced yield improves machinability). Ultimate tensile strength should exceed 90,000 psi, and 40 per cent elongation is probable in small castings.

Plastic Pipe for Corrosive Fluids

Fluids such as wet chlorine, hydrochloric acid, hot caustic soda, and liquid nitrogen will not corrode pipe, fittings, and valves molded of or lined with Kynar vinylidene fluoride resin. Useful temperature range of the new resin is −80 to 300 F. It weighs only about one-fifth as much as steel, is strong, tough, nonflammable, thermally stable, and resists embrittlement at low temperatures. All-plastic and plastic-lined components are being produced by Tube Turns Plastics Inc., Louisville, Ky.; the resin was developed by Pennsalt Chemicals Corp.

COMPLICATED PARTS of any ferrous or nonferrous material can be made with a new photoetching process announced by Industrial Electronic Engineers Inc., North Hollywood, Calif. The parts can be as thin as 0.10 mil; hole and line tolerances, as close as ±0.0002. In the photoetching process, drawings are enlarged as much as 40 times, with accuracy of ±0.020 in. Typical parts are gyro springs, leaf springs, magnetic-head laminations, printed-circuit coils, and shim spacers.

DIAMONDS ARE A GOOD FRIEND of the surface finisher, according to findings of E. H. Hull, of General Electric's Research Laboratory. He reports that diamond-burnishing of metals produces smooth surface finishes and work-hardened surface layers. Accuracy of the original surface is preserved or improved, since no metal is removed. Burnishing enhances the appearance of metal, improves leak-tightness of vacuum seals, and should reduce initial wear in bearing journals, says Mr. Hull.

HARD-TO-FORM METALS are shocked into shape by equipment that adapts explosive forming to electro-hydraulic power. In a technique developed at the General Engineering Laboratory of General Electric Co., the metal, the die, and an electrode assembly are submerged in a tank of water. An electric arc heats, vaporizes, then converts the water to plasma; rapid heating and expansion of the plasma produces a shock wave which uniformly stretches the metal to conform to the die shape.

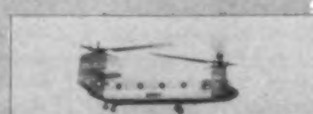
CERAMIC-FACED DIES may soon be able to handle billets of refractory metals at temperatures as high as 4000 F. This prediction was made by Air Force researchers after they completed experimental extrusion of molybdenum, tungsten, titanium, tantalum, and their alloys. Steel extrusion dies sprayed with aluminum oxide withstood 3400 F with no apparent die wash. Use of other coatings, such as zirconium oxide or zirconium silicate, is expected to raise this temperature limit.

Current roster of 13 aircraft will be cut to these six types:

Combat Surveillance Aircraft —Fixed-wing AO1 Mohawk, now being delivered to troop units, carries the latest electronic and photographic surveillance equipment.

Light Observation Helicopter—Four-place, turbine-driven craft is being developed for company, battalion, and combat-command-level observation, and liaison.

Utility/Tactical Transport—Already in quantity production, Bell Aircraft's HU1 Iroquois will be used almost exclusively at the front. It can carry 11 passengers or considerable cargo and can be converted to a deadly firing platform.



Transport Helicopter—Biggest of the helicopters, the HC1B Chinook can carry 34 fully armed troops or about 10 tons of cargo, giving air mobility to many of the Army's heavier vehicles and ordnance.

Utility Transport Airplane—Modified commercial craft, built by Beech, is used principally for command liaison.

STOL Transport — Known among troops as the "beans and bullets" carrier, the AC1 Caribou is a versatile STOL aircraft that can take off and land in a few plane lengths.

Circle 26-1 on Page 19 for extra copy.

Army Begins Buildup of a

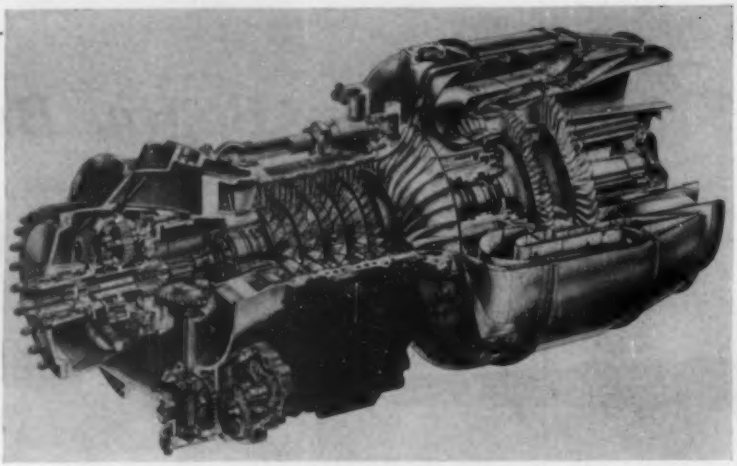
Beans-and-Bullets Air Arm

All-Turbine Fleet, 8000-Strong, Planned by 1970

EVER since war became an organized endeavor, its outcome has depended on the mobility of men and machines and their relative speeds of deployment by the two opposing forces. Classic tactical examples of victory by mobility were set by German armor during World War II. The same techniques and equipment, with certain variation and refinement, would probably prevail today on the same battlefronts. But they haven't proved successful in the numerous small-scale wars that have erupted since World War II. In most instances, the nature of the terrain has ruled out the conventional combat vehicle; tanks are simply not at home in jungles, rice paddies, and mountainous areas.

Because brushfire wars occupy an important place in the strategic concepts of several nations, tactical equipment for fighting them has become of first priority. The U. S. Army has reacted by placing major emphasis on a fleet of slow, low-flying aircraft that can shuttle troops and equipment between critical battlefront areas. These

Bell Iroquois armed with six antitank rockets



All aircraft to be used by Army field forces, except the AC1 Caribou, will be turbine powered. Typical powerplant is the Lycoming T-53-L-1; it powers both the fixed-wing Mohawk and the Iroquois helicopter, is interchangeable between aircraft in the field. In the case of Iroquois, the engine can be lifted and replaced in 20 min. A free-turbine engine, the T-53 can be used for turboprop, helicopter, or turbojet. The engine package is the same in all versions, reduction gearing is merely changed or eliminated to suit the application.

aircraft can also serve as mobile rocket platforms with devasting firepower.

Army's concept of aerial logistics and firepower has been outlined by Brig. Gen. Clifton F. Von Kann, director, Army Aviation: "The Navy offers a good example of a military force exposed to a radical change in tactics by the introduction of aircraft. Fast carrier task forces in the Pacific exerted their influence over a radius of 300 to 400 miles. They were able to control everything within this radius by using the mobility of the aircraft. There is much in this example that can be applied to land battle; in many ways, aviation has more to offer over land than over water. On land we can combine the two most mobile elements in warfare: The foot soldier and the airplane. In the past this application was limited because the airplane could not live with the foot soldier on the battlefield and be immediately available for use in ground maneuver. Turbine-powered helicopters and excellent STOL aircraft have cleared this obstacle. Since a small unit may readily be afforded the same atomic support as a large unit, it follows that a small, agile, highly skilled group stands a first-class chance of destroying a larger and heavier one. Elusiveness and dispersion now provide the greatest chances of survival. Mars is no longer on the side of the biggest battalions."

Army's 10-year program to incorporate this philosophy involves three major changes in flight hardware:

- Reduction of the number of helicopter and fixed wing models from 11 to 6.
- Conversion from piston to turbine engines.
- Standardization of fuels used by all Army aircraft.

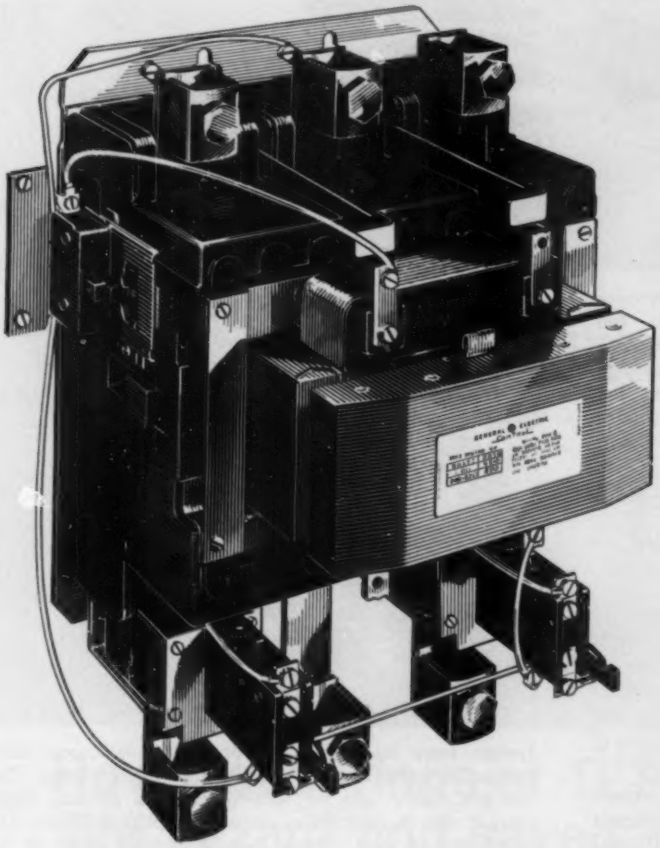
Three of the six replacement aircraft are opera-

The only modified commercial plane retained by the Army is the Beech L23F Seminole. It will be used principally for command liaison, but can be converted to carry stretchers or high-priority cargo. It will seldom see front-line duty.

Most powerful American helicopter in production today, the Boeing-Vertol HC-1B Chinook has a maximum payload of more than 7 tons, will carry 34 fully equipped troops. Powered by two Lycoming T-55 gas turbines, each rated at 2200 eshp, the craft will cruise at about 150 mph. A stability augmentation system gives Chinook flight characteristics similar to fixed-wing aircraft. The big helicopter also has a sealed fuselage permitting water landings.

THE NEWEST STARTER FROM GENERAL ELECTRIC

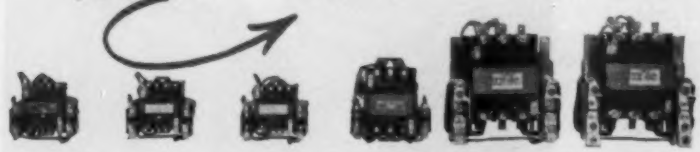
. . . and what it means to you



IMPORTANT

SIZE 5 DIMENSIONS REDUCED EVEN FURTHER!

NEW NEMA SIZE 5 STARTERS now added to G-E 100-Line feature extremely small size, plus all 100-Line benefits: Height—14¼"; Width—~~11¾"~~ 11½" Area—~~167.4~~ 163.8 sq in.



NEMA SIZE 00	NEMA SIZE 0	NEMA SIZE 1	NEMA SIZE 2	NEMA SIZE 3	NEMA SIZE 4
H-4 1/2"	H-4 1/2"	H-4 1/2"	H-6 5/8"	H-9 5/16"	H-9 13/16"
W-5 3/32"	W-5 3/32"	W-5 3/32"	W-6 1/4"	W-8 3/4"	W-8 3/4"
A-22.9 sq in.	A-22.9 sq in.	A-22.9 sq in.	A-41.4 sq in.	A-81.4 sq in.	A-85.8 sq in.

Progress Is Our Most Important Product

GENERAL ELECTRIC

6 DISTINCT ADVANTAGES YOU CAN'T GET ELSEWHERE

General Electric announces the development of new NEMA Size 5 magnetic starters and contactors—up to 65 percent smaller in open forms than previous designs.

This addition to the G-E 100-Line Starter "family" means you can now get seven sizes that give you six distinct, measurable advantages you cannot get from any other single brand of motor control. They are:

1. **SMALLER SIZE**—particularly in the more popular forms (Sizes 0 and 1). On larger forms, reduced height (as much as 41 percent on Size 5 units alone) saves critical panel space. See dimensions at left below.
2. **EASE OF WIRING**—all terminals are "out front," visible and accessible. Wiring for all sizes is straight through (this can save up to $8 in wire alone for Size 5 installations where line leads come in top and out bottom).
3. **SIMPLIFIED MAINTENANCE AND INSPECTION**—contacts can be inspected or coils changed in less than a minute on all sizes. No tools required on Sizes 00 through 4; only a screwdriver on Size 5.
4. **MORE MODIFICATION KITS**—industry's most complete line lets you modify existing starters on-the-spot in minutes to meet special operating conditions. Result: reduced change-over expense. All starter enclosures have cover knockouts for field-addition of push buttons, selector switches, and indicating lights. Other kits include auxiliary contacts, third overload relay, fuse clips, and coils.
5. **FIELD-PROVED DESIGN**—well over 1,000,000 units are operating in the field today. Exhaustive testing in laboratories and on customer applications since the 1957 introduction is your assurance of 100-Line dependability.
6. **"FAMILY" DESIGN BENEFITS**—G.E.'s 100-Line offers all forms and sizes in the same basic design. You benefit from common installation procedures; common maintenance and inspection techniques; reduced inventory; and such operating conveniences as adjustable overload relays for all sizes. Mounting dimensions for Sizes 00, 0, and 1 are identical; so are dimensions for Sizes 3 and 4. Common mounting dimensions and wiring procedures save time and space during panel layout; also when changes occur in horsepower requirements or industry specifications.

Meet all your control requirements—up through 200 hp—with the uniform, field-proved 100-Line, available in all popular forms: Sizes 00, 0, 1, 2, 3, 4, and 5 contactors and starters; plus combination starters; reversing and two-speed controllers. Contact your G-E sales engineer or distributor, or write Section 811-29, General Electric Company, Schenectady 5, N. Y.

Circle 214 on Page 19

Stall speed of 59 knots is a favorable performance characteristic of Grumman's 10,000-lb Mohawk. Designed for battlefield observation and surveillance (note instrument pod, above), the aircraft is powered by two Lycoming T-53-L engines, will cruise at 264 knots. Ground-roll and takeoff-distance over a 50-ft obstacle are 793 ft.

tional, two are in the test-flight stage, and one is in the planning stage.

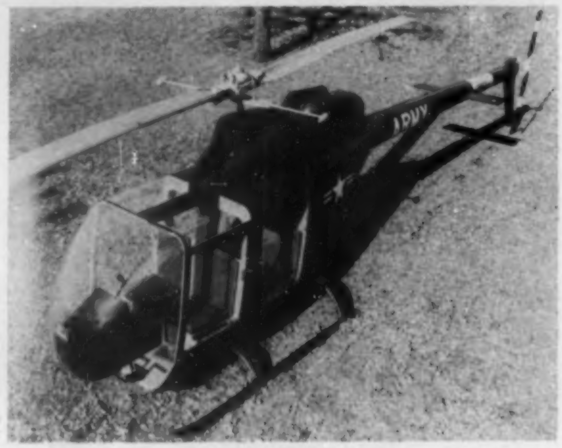
The Army now has 5500 aircraft, of which about 50 per cent are helicopters. By 1970, it will have 8000 aircraft. More than 75 per cent will be helicopters.

Where present Army combat aircraft require many different grades of fuel, the six replacement aircraft will need only two or three different grades, cutting initial investment and reducing the burden of transportation and storage.

At combat-division level, logistics will be further simplified: A division now uses six different aircraft, burning three or four different fuels, having few interchangeable parts, and using piston engines requiring a relatively high amount of maintenance.

Under the 10-year program, these six aircraft will be replaced with three aircraft all using the same grade of kerosene, and two—the AO1 Mohawk and the HU1 Iroquois—have interchangeable engines.

The Army's new transport team, the Chinook helicopter and the Caribou airplane, may be replaced before 1970 by a VTOL craft expected to incorporate all the desirable characteristics of both members of the present team. How fast the replacement comes along will depend on results of the present triservice VTOL program.

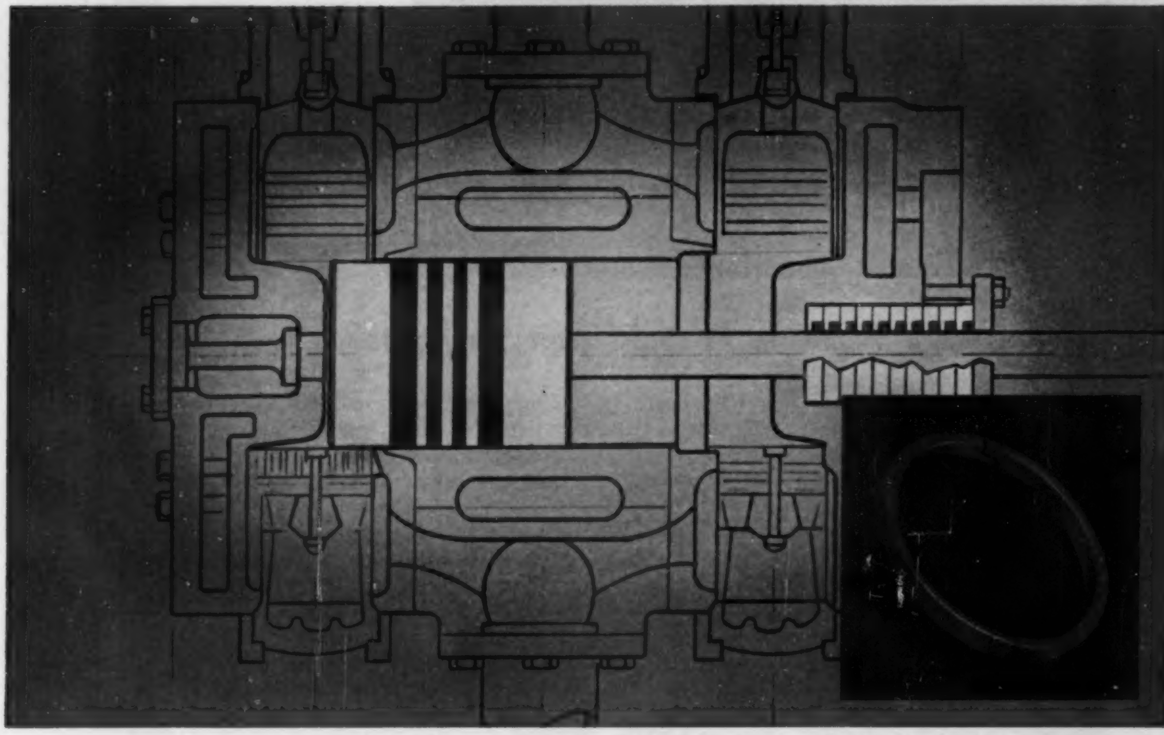


Typical entry in Army's light-observation-helicopter competition is under development at Hiller Aircraft Corp. The four-place ship will be turbine powered (Allison T-63), carry a 400-lb payload in addition to pilot and fuel, and cruise at 126 mph. Army expects to order 4000 of the craft during the next 10 years.

Typical combat capabilities of STOL aircraft include operation from extremely adverse terrain. During evaluation of DeHavilland's Caribou, the aircraft made landings and takeoffs from a mud strip that had previously been ploughed to a depth of 14 in. Caribou can takeoff and land within a distance of 1000 ft.

DU PONT

TEFLON®



How piston rings of TEFLON® eliminated fire hazard and saved $4,500 per year

CAN YOU AFFORD NOT TO USE TEFLON?

- Piston rings of Du Pont TEFLON are your most economical choice whenever product contamination is a problem . . . whenever maintenance costs should be cut . . . whenever lubrication should be reduced or completely eliminated.
- Rings of Du Pont TEFLON can permit bone-dry operation . . . provide more uniform output because there is less gas blow-by . . . reduce danger of fretting, galling, and cylinder wear.
- Rings of TEFLON are not brittle . . . resist chipping, cracking, breaking . . . installation, storage, and handling are easier.
- Rings of TEFLON make possible substantial savings in operating, maintenance, and replacement costs.

Oil contamination in an instrument air system caused serious problems in a large manufacturing plant. Oil plugging the lines not only led to heavy maintenance costs, but also created a dangerous fire hazard. Converting the eight instrument air compressors to piston rings of TEFLON solved the problems and saved the plant money.

The greatly reduced lubrication required with rings of TEFLON (no oil at all was added to the cylinder) eliminated the oil contamination and system plugging. In addition to cutting the plant's maintenance costs substantially, the rings of TEFLON lasted longer than the previously used carbon rings, saving $3,000 per year in ring cost, and virtually eliminated cylinder wear, saving another $1,500 per year in cylinder refinishing.

If you are buying a new compressor, specify rings and packings of a TEFLON TFE resin. To convert your present equipment, check with your compressor manufacturer or qualified ring supplier for engineering and design assistance. For further information, write: E. I. du Pont de Nemours & Co. (Inc.), Dept. MD-12-T, Room 2526, Wilmington 98, Delaware.

In Canada: Du Pont of Canada Limited, Box 660, Montreal, Quebec.

DU PONT REG. U. S. PAT. OFF.

TEFLON®
FLUOROCARBON RESINS

TEFLON is Du Pont's registered trademark for its family of fluorocarbon resins, including TFE (tetrafluoroethylene) resins and FEP (fluorinated ethylene propylene) resins.

BETTER THINGS FOR BETTER LIVING . . . *THROUGH CHEMISTRY*

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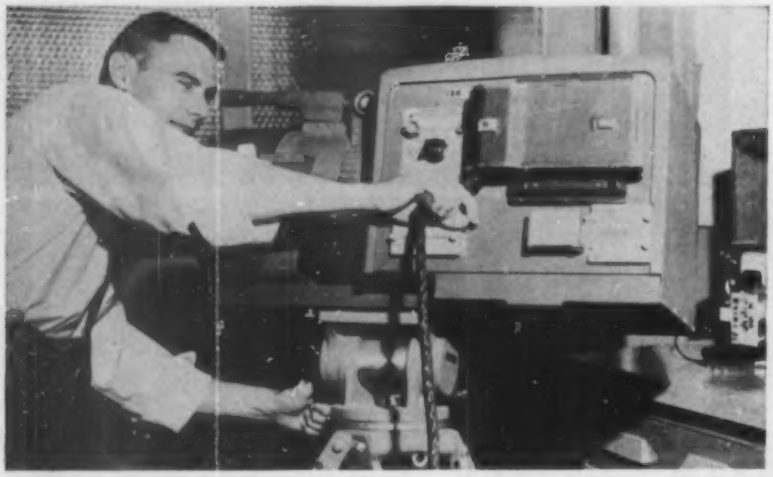


Temperature distribution over a large area can be recorded by the Barnes infrared camera. The device uses a scanning mirror to monitor the target, sweeping horizontally to direct infrared energy at a radiometer. The radiometer drives a glow tube whose brightness is made to vary with temperature of the target being measured; a second mirror, coupled to the scanner, reflects light generated by the tube to the proper part of the film.

Sweep Camera Pinpoints Printed-Circuit Hot Spots

BY TAKING pictures of printed circuits and electronic components, IBM engineers have developed a new method of making sure computer circuit boards come up to optimum temperature but don't overheat. The photographs, obtained with an infrared scanning camera, pinpoint hot spots by recording temperatures as shades of gray. Other measuring techniques don't work well because of the problems introduced by high-density packaging and accessibility of only one side of the printed wiring.

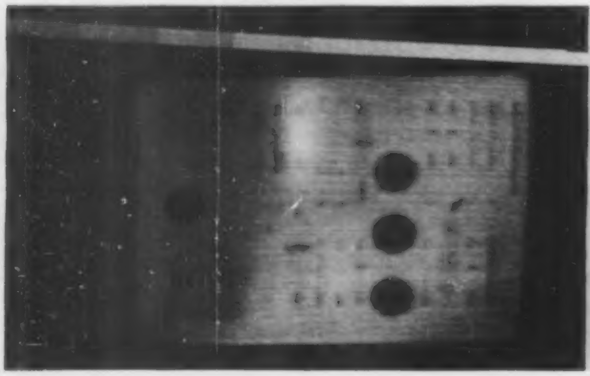
Components needing greater heat-dissipating ability, and circuit boards requiring thicker conductor sections to accommodate high current levels can be modified during the design stage. By isolating trouble spots before the boards go into mass production, the infrared technique extends circuit life, increases reliability, and reduces engineering costs, according to IBM.

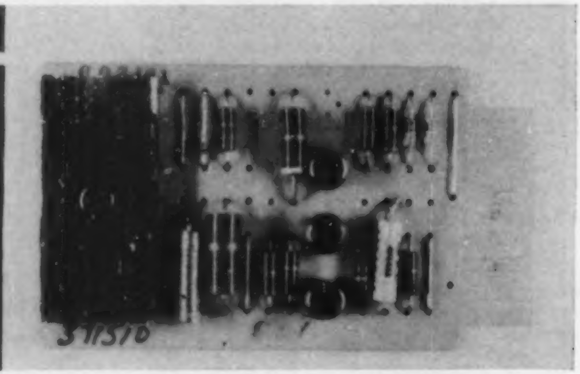
Pioneered by Barnes Engineering Co., Stamford, Conn. (designers of the camera), the infrared method is called thermography. It allows both rough and fine measurements of temperature. By visually comparing the gray tones produced with a reference strip automatically inserted into each photo, photographers can accurately interpret shadings. The total range of the instrument, from white to black, may be set up as 150 C, or it can be as little as 4 C, depending on the scale factor selected.

Although the application of thermography is still new at IBM, the engineering staff visualizes a number of instances where the technique may prove useful:

- It may show that heat sinks designed into many boards are inadequate for keeping temperatures within limits.
- It may point up that certain components have too high ratings, or take too long to heat up.
- It may shed new light on the current-carrying capacity of conductors.

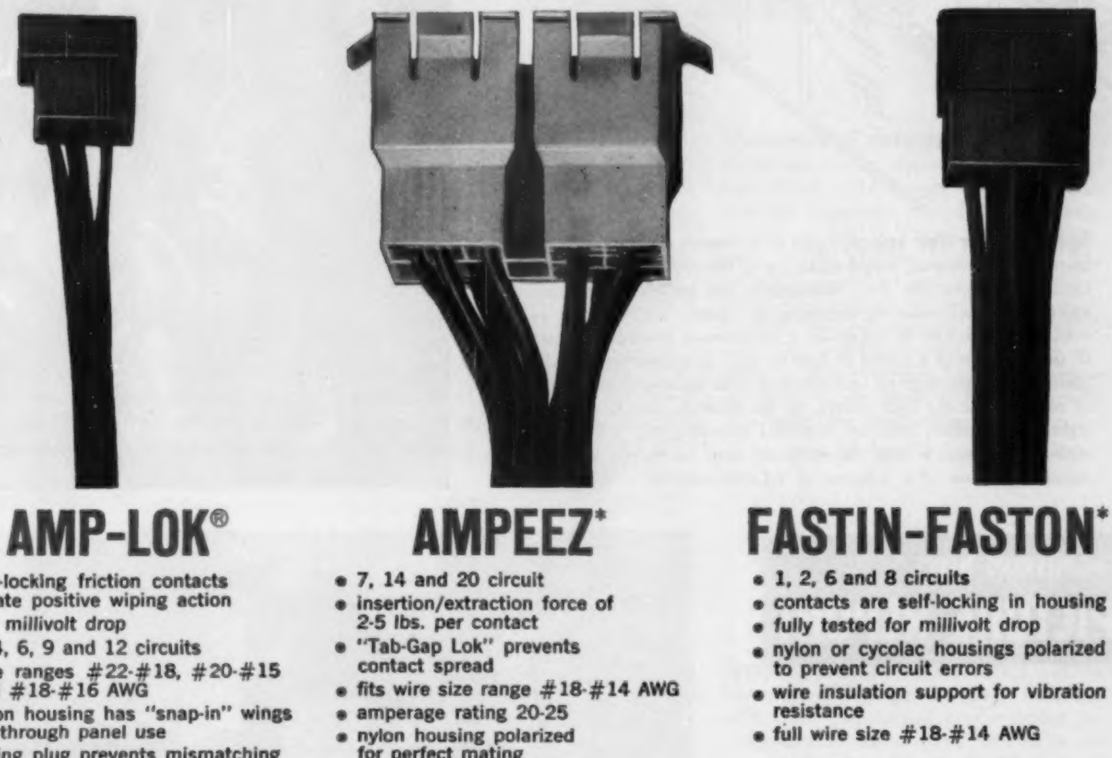
The camera can also be used to check heat distribution over an entire apparatus and may lead to regrouping of computer subassemblies for a more favorable heat balance, or modification of forced-air cooling systems.





When the experimental circuit board (right) was tested, one resistor overheated (shown white in the infrared photo, (left), but all four transistors remained relatively cool (black). The reference strip at the upper edge of the photo permits visual determination of temperatures of the various components. Before the infrared technique was developed, temperature data were extremely hard to obtain for printed circuit boards heavily packed with components.

This **AMPin-cert*** connector line **GIVES YOU BOTH** economical assembly, easy maintenance **WITH ALL 3**



AMP-LOK®

- self-locking friction contacts create positive wiping action
- low millivolt drop
- 3, 4, 6, 9 and 12 circuits
- wire ranges #22-#18, #20-#15 and #18-#16 AWG
- nylon housing has "snap-in" wings for through panel use
- keying plug prevents mismatching caps in side-by-side mounting

AMPEEZ*

- 7, 14 and 20 circuit
- insertion/extraction force of 2-5 lbs. per contact
- "Tab-Gap Lok" prevents contact spread
- fits wire size range #18-#14 AWG
- amperage rating 20-25
- nylon housing polarized for perfect mating
- mounts flush—only .125" projects from panel front

FASTIN-FASTON*

- 1, 2, 6 and 8 circuits
- contacts are self-locking in housing
- fully tested for millivolt drop
- nylon or cycolac housings polarized to prevent circuit errors
- wire insulation support for vibration resistance
- full wire size #18-#14 AWG

* Trademark

This line of AMPin-cert Connectors gives you minimum insertion and withdrawal forces, maximum amperage ratings, resistance to vibration, corrosion and environmental factors . . . everything to assure lower assembly costs, rugged performance and simplified maintenance. Check these features and see how they fit your design plans. Any additional information you may need will be sent on request.

AMP INCORPORATED

GENERAL OFFICES: HARRISBURG, PENNSYLVANIA

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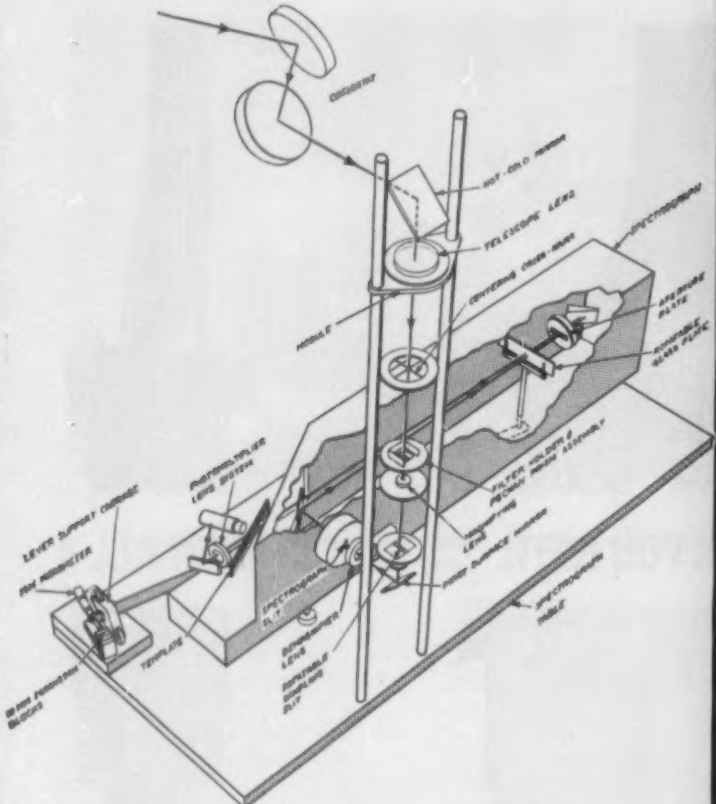
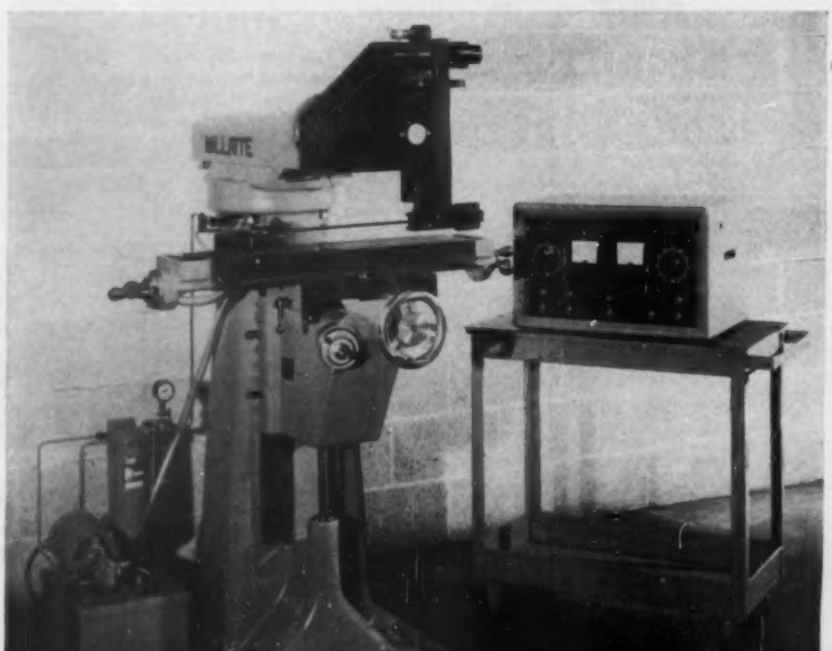


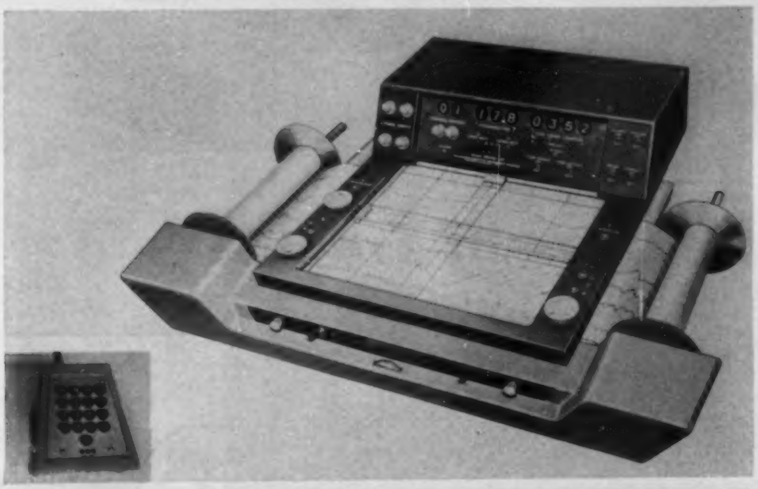
Speedometer for space, goal of a research project at the Franklin Institute Laboratories, would make use of the Doppler effect, applied to light waves from the sun. Researchers are considering the template spectroscopy technique for obtaining an optical "fix" in space navigation. This consists of using—as a template—a photographic negative of the spectrum of a source of light at rest. It is positioned in the focal plane of the spectrograph and matched with the spectrum of the source in motion. As the light source, or the observer, moves in the line of sight, the spectrum lines are displaced according to the Doppler principle. The amount that the template must be moved to restore the match condition is a measure of relative velocity.

ENGINEERING NEWS PICTURE REPORT



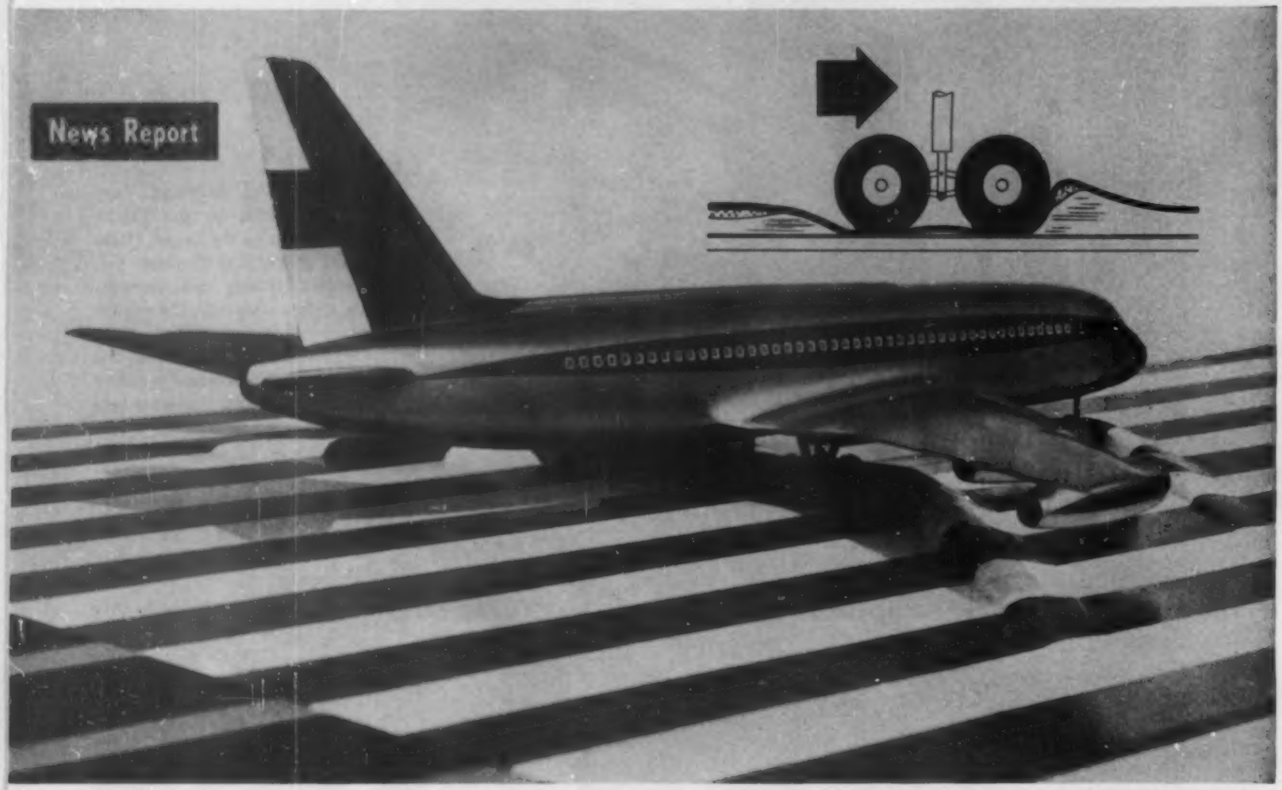
Made-to-order defects —for checking the accuracy of ultrasonic and eddy-current inspection equipment—are the products of this machine tool. Operating on the electro-discharge machining principle, it makes crack-like and pin-hole "defects" in sheet, tubing, and other mill products. Precision notches (1 in. by 0.002 in. by 0.030 in. deep) can be placed anywhere on sheet or bar, up to 14 in. inside of a tube ⅜ in. ID or larger, and up to 7 in. inside tubing as small as 3/16 in. diam. Pin holes as small as 0.005 in. diam can be made. Builder is Metcut Research Associates Inc., Cincinnati.

Slopes of 45 degrees are taken in stride by the Trackmaster, built by the Logan, Utah, works of Thiokol Chemical Co. Besides climbing and descending such a steep hill, the vehicle can travel along the face of it. Lightweight and economical, the Trackmaster uses many standard automobile parts. Innovations in suspension and power selection give it the ability to travel over difficult terrain.



Thousands of data points can be reduced in a day by this new, low-cost digital data reader. The system, built by Gerber Scientific Instrument Co., Hartford, Conn., consists of any X-Y reading head, 16-in. paper or film transport, and keyboard. The reading head can be used separately, with a 35-mm film projector, or with Gerber's 66-in. scanner. Multiple channels can be handled, each with a different scale factor and zero reference; zero references can be located at any point on the graph. The reading head costs $4475; the basic system, $4975.

Computer-simulated acoustics aid in the design or redesign of concert halls and auditoriums. A method of simulating the transmission of sound waves in a room has been developed by Dr. M. R. Schroeder of Bell Laboratories Acoustics and Visual Research Dept. He feeds information on paths and speed of sound waves along with reverberation time of the proposed hall into the computer. A magnetic tape contains speech or music. Dr. Schroeder is shown in Bell's anechoic chamber, listening to music played back the way the computer says it would sound in a proposed auditorium.

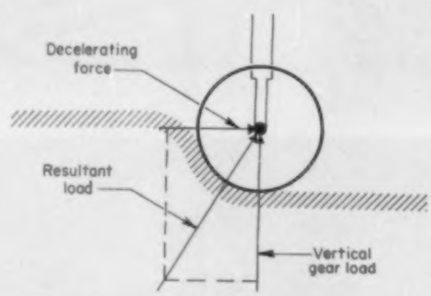


Gentle Stops for Jets in Trouble

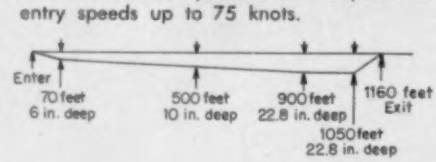
WITH the introduction of jet airliners, many of the nation's airport runways have become marginal under adverse operating conditions. Accidents due to landing overruns or short landings have increased noticeably. No cure, in the form of an emergency arresting system, has proved suitable for commercial aircraft.

Military systems, including the hook-and-cable system and nets that are thrown up at the end of the runway to catch an entire aircraft, are successful to the degree that lives are saved, but in most cases the aircraft is damaged. Also, military use of the hook-and-cable system has been successful largely because the crew is usually alerted to an impending emergency, and each member is strapped securely in place to begin with. This obviously wouldn't be true in regard to passengers on a commercial transport. Human-factors studies have determined that 0.8 g is the top rate of deceleration that can be tolerated, without injury, by unsuspecting passengers.

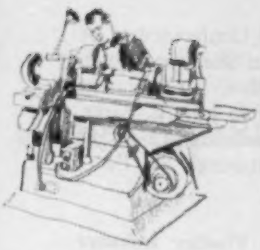
An unusually promising system, now pending final analysis by NASA (for FAA), was outlined at a recent SAE meeting by two engineers—E. Groothius and J. Thousand—of Nortronics Div., Northrup Corp. Their so called De-Cel arresting system consists of a long shallow pool of water covered by a plastic sheet. In extensive tests, it has proved to be more efficient than similar open-water basins. The plastic cover prevents water waves from damaging the aircraft, and by containing the waves, increases braking effectiveness of the displaced fluid.

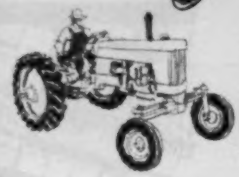


Profile of a De-Cel Basin: Computer analysis and scale model tests by Nortronics and NASA have determined the general configuration for a De-Cel arresting pool. Simulated aircraft was a Boeing 707. Test results indicated that a covered De-Cel basin, 600-700 ft long, sloped to a depth of 2 ft would satisfactorily arrest the airplane at entry speeds up to 75 knots.

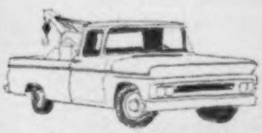


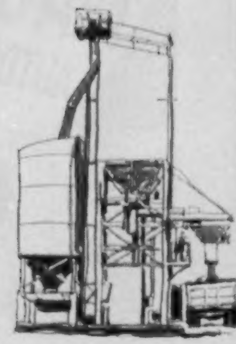
BRAKE HEADQUARTERS OF THE WORLD

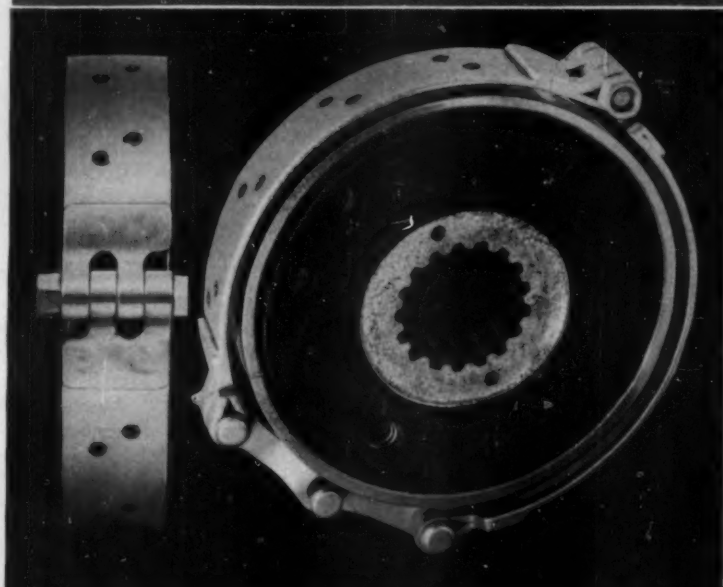




Bendix mechanical brake—built to "take it" under severest wear.







Bendix band/disc brake—greater braking capacity/smaller package.

See the Bendix exhibit at the SAE Show, Detroit, January 8-12

BENDIX SMALL, MULTI-PURPOSE BRAKES GIVE BETTER CONTROL IN UNLIMITED APPLICATIONS

Practically any application you can think of—golf cart, power saw, tractor, oil rig, steam shovel—can use the benefits of Bendix small, multi-purpose brakes. **The Bendix® band/disc brake** gives greater torque capacity while reducing brake size. It provides maximum lining area in minimum space; permits rapid heat dissipation. **The small mechanical brake** is economical, easy to install and adjust, requires little maintenance. Light and compact, it packs man-sized power in 4 lbs. of brake and drum. Available in complete range of sizes. These small, multi-purpose brakes could be the answers you've looked for. Write us at South Bend, Indiana, for sizes and actuations available.

THE Bendix CORPORATION

Bendix Products Automotive Division

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Circle 218 on Page 19

Meetings and Shows

Jan. 8-12—
Society of Automotive Engineers Inc. 1962 Automotive Engineering Congress and Exposition to be held at Cobo Hall, Detroit. Additional information can be obtained from society headquarters, 485 Lexington Ave., New York 17, N. Y.

Jan. 22-24—
Institute of the Aerospace Sciences. Thirteenth Annual Meeting to be held at Hotel Astor, New York. Further information can be obtained from IAS headquarters, 2 E. 64th St., New York 21, N. Y.

Jan. 22-25—
National Plant Engineering & Maintenance Show to be held at Convention Hall, Philadelphia. Further information can be obtained from show managers, Clapp & Poliak Inc., 341 Madison Ave., New York 17, N. Y.

Jan. 25-27—
National Society of Professional Engineers. Winter Meeting to be held at the King Edward Hotel, Jackson, Miss. Further information is available from NSPE, 2029 K St., N.W., Washington 6, D. C.

Jan. 29-Feb. 1—
American Society of Heating, Refrigerating and Air Conditioning Engineers. Semiannual Meeting to be held at the Chase-Park Plaza Hotel, St. Louis. Additional information can be obtained from ASHRAE headquarters, 345 E. 47th St., New York 17, N. Y.

Jan. 29-Feb. 2—
American Institute of Electrical Engineers. Winter General Meeting and Electrical Engineering Exposition to be held at the Hotel Statler and New York Coliseum, New York. Additional information is available AIEE headquarters, 345 East 47th St., New York 18, N. Y.

Jan. 30-Feb. 2—
Society of Plastics Engineers Inc. Annual Technical Conference to be held at the Penn-Sheraton Hotel, Pittsburgh. Further information can be obtained from John E. Parks, H.P.M. Div., Koehring Co., 512 Empire Bldg., Pittsburgh 22, Pa.

Feb. 6-8—
Society of the Plastics Industry Inc. Seventeenth Reinforced Plastics Division Conference to be held at the Edgewater Beach Hotel, Chicago. Further information is available from SPI headquarters, 250 Park Ave., New York 17, N. Y.

Feb. 15-17—
Golden Gate Metals Conference to be held at the Fairmont Hotel, San Francisco. Sponsor is American Society for Metals. Further information is available from Norman McLeod, 1605 Solano Ave., Berkeley 7, Calif.

Feb. 19-21—
Institute of the Aerospace Sciences. Range Reconnaissance & Tracking of Aerospace Vehicles Meeting to be held in San Francisco. Additional information is available from IAS headquarters, 2 E. 64th St., New York 21, N. Y.

March 4-8—
American Society of Mechanical Engineers. Gas Turbine-Process Industries Conference to be held at Shamrock Hilton Hotel, Houston. Further information is available from Meetings Dept., ASME, 345 E. 47th St., New York 17, N. Y.

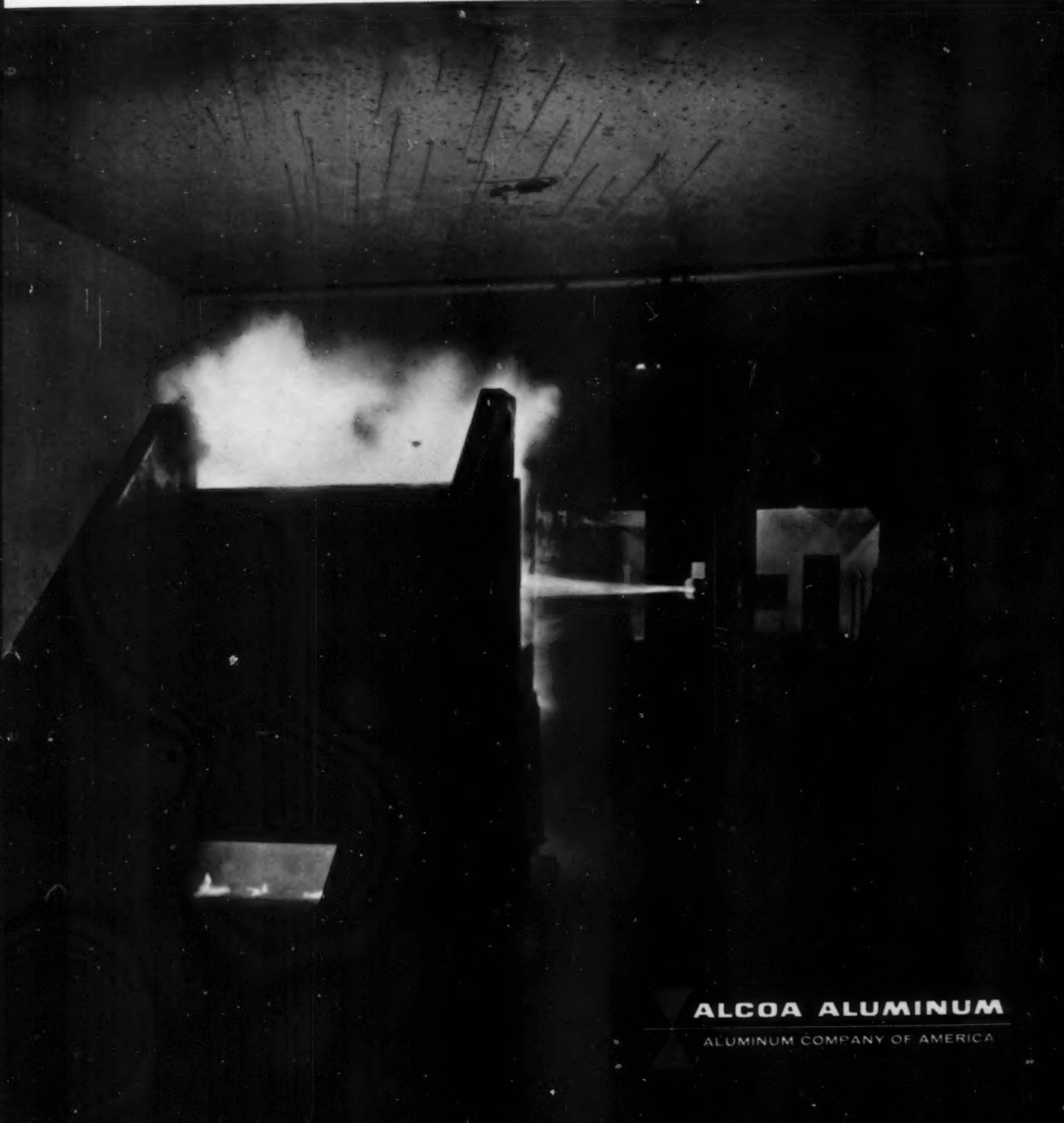
Short Courses and Symposia

Jan. 15-19—
Seminar on Simulation and Mathematical Programming for industrial engineers, to be held at the University of Wisconsin. Further information is available from Engineering Institutes, 3030 Stadium, University of Wisconsin, Madison 6, Wis.

Jan. 16-17—
Engineering Institute on Industrial Adhesives Applications to be held at University of Wisconsin. Technical sessions will cover basic principles of adhesive bonding, some important applications of adhesives,

Circle 219 on Page 19→

When an aluminum weld stops a 37mm high-explosive shell...



When an aluminum weld stops a 37mm high-explosive shell... that's Alcoa Total Ability at work!

Blam! A 37mm high-explosive shell slams home right into the weld. It holds, and weldable Alcoa® Aluminum Armor Plate passes its last test. Next stop: armored vehicles for our defense forces, giving personnel the protection of steel at a saving in weight . . . adding vital speed, range and air-borne mobility.

This 1¼-in. "H" plate of Alcoa Alloy 5083 is welded by the inert gas shielded method, using Alcoa 5356 consumable electrode. Aluminum is *field-weldable!* Portable gear goes along by jeep or mechanical mule, independent of power or cooling water.

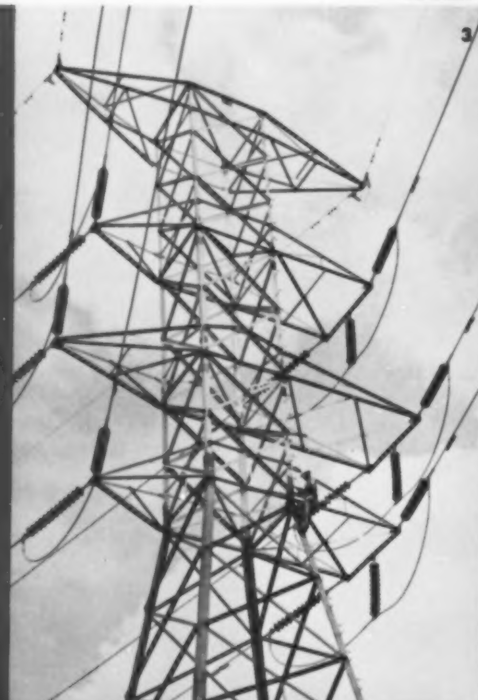
Whatever the joining method for aluminum, you get more savvy (and the best materials) from Alcoa. It follows. Alcoa perfected most of them. Welding, brazing or soldering? Alcoa knows how to boost quality, hold down costs. For mechanical fastening Alcoa makes bolts, nuts, rivets, washers, screws and "specials" to your order. And they're made of the proper alloy, fully heat-treated to insure lasting strength.

Alcoa also supplies aluminum sheet and plate, extrusions, impacts and castings in all alloys, tempers and finishes. Stands to reason, then, we've no favorites among them. Your needs call the shots for *Alcoa Total Ability!* Find out more from the Alcoa sales office near you, or write: Aluminum Company of America, 856-Z Alcoa Building, Pittsburgh 19, Pa.

Entertainment at Its Best . . . ALCOA PREMIERE with Fred Astaire as Host . . . Tuesday Evenings, ABC-TV

ALCOA ALUMINUM

ALUMINUM COMPANY OF AMERICA



ALCOA ALUMINUM: EASY TO JOIN BY ANY METHOD!

1. Aluminum pleasure boat combines light weight and high speed with the rugged strength and durability of all-riveted construction.

2. Aluminum superstructure for the guided-missile destroyer *U.S.S. Dewey* uses Alcoa alloys welded by IG consumable-electrode method.

3. Alcoa Aluminum superstructure for electrical transmission tower is made of welded subassemblies, bolted together in the field.

4. Aluminum leisure furniture made of Alcoa welded tube keeps its smart good looks for years, fastened *right* with rustproof aluminum rivets, sheet metal screws.

5. All-aluminum electrical substation: Special wide-flange beams are bolted; main and line section buses and taps are welded tube.

6. All-aluminum personnel boat is Alcoa Alloy 5456. Welded *faster* than steel, it ends sandblasting, metalizing, stress-relieving.

design of joints for adhesive bonding, equipment requirements for adhesive bonding, evaluation techniques for adhesives, and principles of adhesive formulation. Additional information can be obtained from William W. Wuerger, Institute Coordinator, Engineering Dept., Extension Div., University of Wisconsin, Madison, Wis.

Jan. 18-19—
Industrial Power Systems Seminar to be held at the University of Wisconsin. Further information is available from Engineering Institutes, 3030 Stadium, University of Wisconsin, Madison 6, Wis.

Jan. 24-26—
Second Symposium on Thermophysical Properties to be held in Princeton, N. J., under the auspices of the Heat Transfer Div. of the American Society of Mechanical Engineers. Further information can be obtained from ASME, 345 E. 47th St., New York 17, N. Y.

Jan. 24-26—
Second Symposium on Thermoplastic Properties to be held at Princeton University, Princeton, N. J. Technical session topics are: Ionized gases, thermodynamic properties, transport properties — theoretical, thermodynamic equilibrium, radiation, computational methods, non-Newtonian fluids, experimental techniques, intermolecular forces and interactions, equations of state, and transport properties—experimental. Additional information is available from Mr. H. Bainbridge, Glenbrook Laboratories, Div. of Sterling Drug Co., P. O. Box 1536, Trenton 7, N. J.

Jan. 25-26—
Research Management Conference to be held at University of Wisconsin. Additional information is available from C. F. Hurc, Conference Co-ordinator, University Extension Div., Dept. of Engineering, University of Wisconsin, Madison 6, Wis.

Jan. 29-Feb. 2—
Short Courses on Measurement Engineering to be held at Arizona State University. Theme of the courses is "How To Obtain Valid Data on Purpose"; they consist of a lecture program and a concurrent

experimental program. About half of the lectures are on basic physical principles on which transducers are based and on fundamental measurement theory, including static and dynamic system behavior and the correlation between them. The other lectures are devoted to measurement problems and approaches in specific areas. Additional information is available from Prof. Peter K. Stein, Associate Professor of Engineering, Measurement Engineering, Engineering Center, Arizona State University, Tempe, Ariz.

Jan. 30-Feb. 1—
Seminar on Standardization to be held at the Barbizon Plaza Hotel, New York. The seminar will cover fundamental philosophy of organized standardization and an analysis of the basic approach to the formation of standards; a review of standardization as an integral function of management and the organization of standards work, particularly on the company level. Further information is available from Dr. John Gaillard, 135 Old Palisades Rd., Fort Lee, N. J.

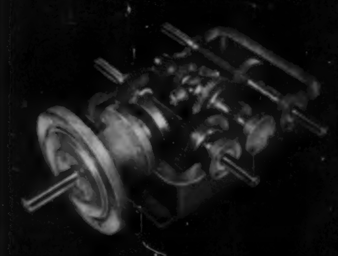
Feb. 2—
Colloquium, "An Application of Statistics to the Dimensioning of Machine Parts," to be held at Northwestern University, Evanston, Ill. Additional information is available from Dept. of Mechanical Engineering, Technological Institute, Northwestern University, Evanston, Ill.

(Please turn to Page 42)

"Think you can carry on from there?"

SPECON

BASIC DIFFERENTIALS... TRANSMISSIONS



BEVEL GEAR DIFFERENTIALS FOR POWER TRANSMISSION PROBLEMS

If you now design your own, you may save time and money by investigating SPECON differential gearing and differential transmissions. Service-proven SPECON modules can be economically incorporated into your own designs and tailored to your specific requirements.

The SPECON differential assemblies are produced in ten sizes ranging from fractional to 250 hp... spider torques to 31,500 lb inches. Also available are standard transmissions and custom designs incorporating these rugged compact differentials.

For engineering data, or FREE TECHNICAL BULLETINS on SPECON DIFFERENTIALS, write —

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New Forging Idea News

How to Improve Parts Design with This Fresh Approach to Forging

Design Refinements suggested by COMMERCIAL's forging experts make many parts in use today better, more economical. Here are detailed examples of only three COMMERCIAL upset forgings which demonstrate how these design refinements have resulted in superior OEM parts at lowered cost.

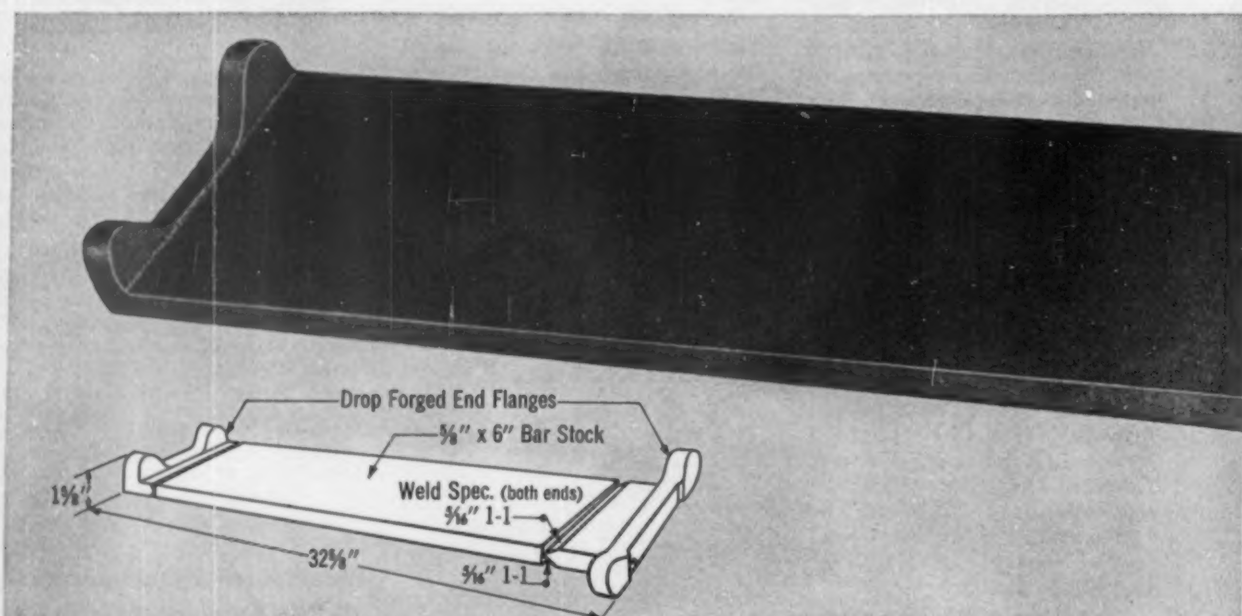
Quality Forgings start with "Forging Quality" rolled steel . . . closely controlled in its making to eliminate defects, to obtain surface and interior soundness, to refine grain structure into a directed fibrous flow. Upset Forgings in closed dies produces by squeeze pressure a "looped" grain flow and permits concentration of grain density at points where the service stresses are calculated to be the greatest. Also, control of the directioning of the inherent fiber-like structure provides for maximum strength of the metal at required stress points. Not only are the properties of the metal improved in all directions, but also the metal structure is refined and compressed resulting in a structural uniformity that renders the metal remarkably free from concealed defects. Result: Tough, strong part—free of hidden defects and surface flaws.

Advantages of Upset Forgings

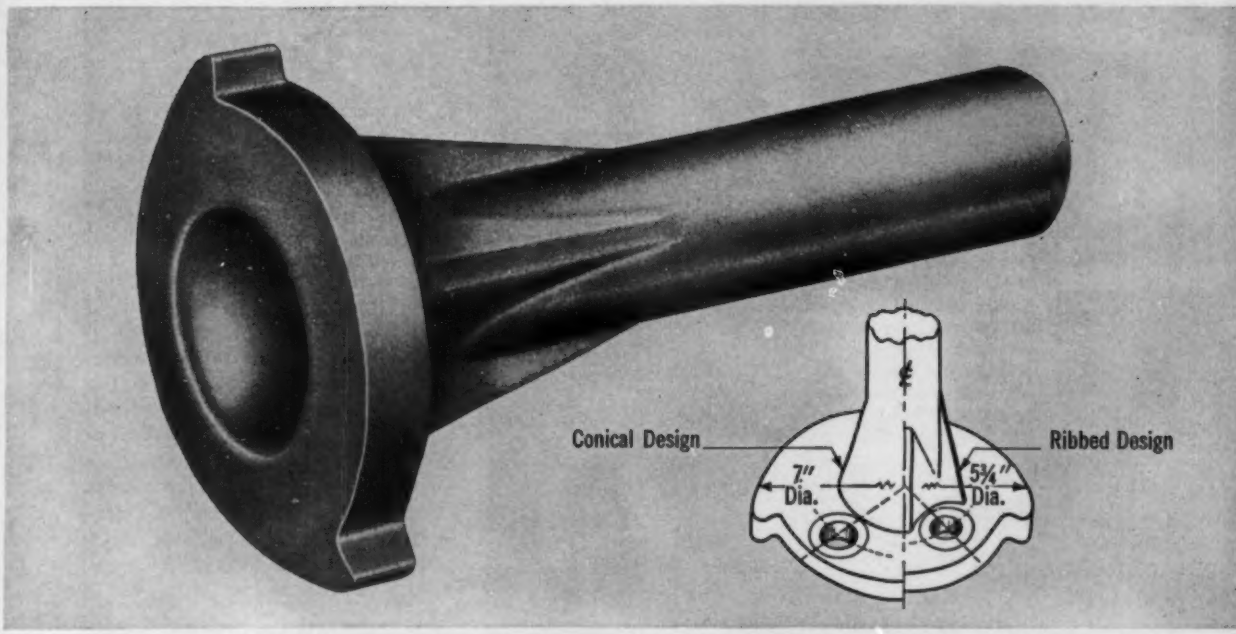
- *Uniform strength, toughness and high fatigue resistance insure longer, more dependable service life for equipment.*
- *Parts made closer to finished dimensions—cuts scrap, reduces machining and finishing time.*
- *Components can be assembled by simple production methods into complex parts.*
- *Uniform response to heat treatment gives desired physical properties of precise degree.*
- *Higher strength-to-weight ratio obtainable—a vital factor in the design complexity of parts for the future.*

Features of Upset Forging by COMMERCIAL

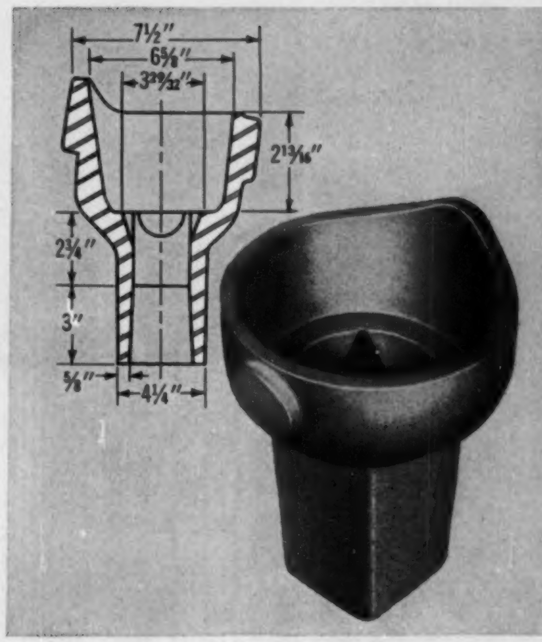
- *Batteries of upsetters from 1½" to 8"—custom or production runs.*
- *Hydra-Jet descaling prior to forging reduces imbedded surface scale.*
- *Magnetic particle depth inspection to detect metal faults before shipment.*
- *"Task Forging" team steeped with experience in producing the unusual upset forging.*



FORGING REPLACES WELDMENT—Structural side bar for agricultural tractor was formerly fabricated from ⅝" x 6" mill-edge bar stock and two drop forged end flanges. COMMERCIAL's redesign called for a homogeneous "metal quality" upset forging. Controlled, fiber-like grain structure is concentrated at stress points. All welding and grinding is eliminated. Warpage disappeared and surfaces are smooth ready for final high lustre finish. Except for automated drilling of holes, now possible due to close tolerance forging, the part is ready for assembly line. Customer benefits have decisively proved the advantages of COMMERCIAL's "Task Forging" team know-how.

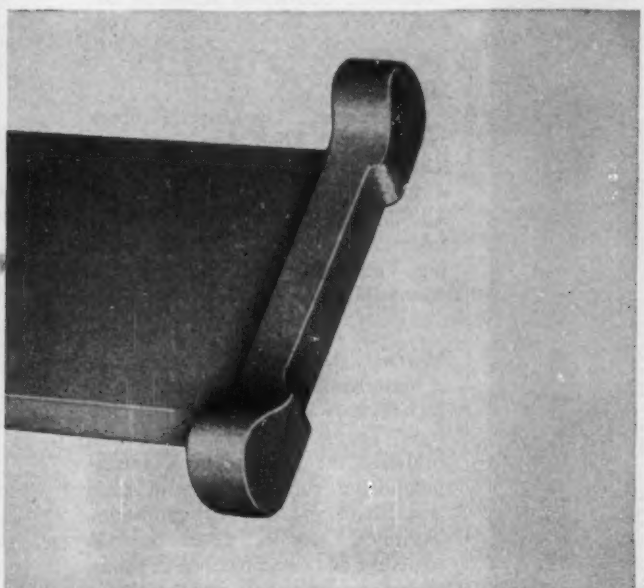


FRESH APPROACH DESIGN SAVES 25%—Lower front end steel tractor spindle, if produced to conventional design, presented excessive weight problem. Symmetrical conical taper from shank to cam head called for 45 lbs. blank weight. COMMERCIAL produced the part to the ribbed taper design with 34 lbs. blank weight. Here is an excellent example where closed die forging most efficiently positions quality metal. Even the cam ears were upset to exact size and location. Result: Smaller part with ample strength, important cost benefits.



UNIQUE FORGING SUPPLANTS CASTING—Unusually shaped axle trunnion socket seemingly was a natural for casting because of asymmetrical trunnion end plus external boss. COMMERCIAL produced the part to finished size via closed dies in an 8" upsetter. Metal had to be displaced both internally and externally. Result: Rejects cut way down, less machining, stronger part, weight reduced, metal saved.

When it's a vital part, design it to be FORGED



While designs are on the board, call on COMMERCIAL'S "Task Forging" team to collaborate with you. Many other ingenious solutions by COMMERCIAL to tough forging problems are detailed in Bulletin 600-P1. Write Commercial Shearing & Stamping Company, Dept. S-51, Youngstown 1, Ohio.

COMMERCIAL
shearing & stamping

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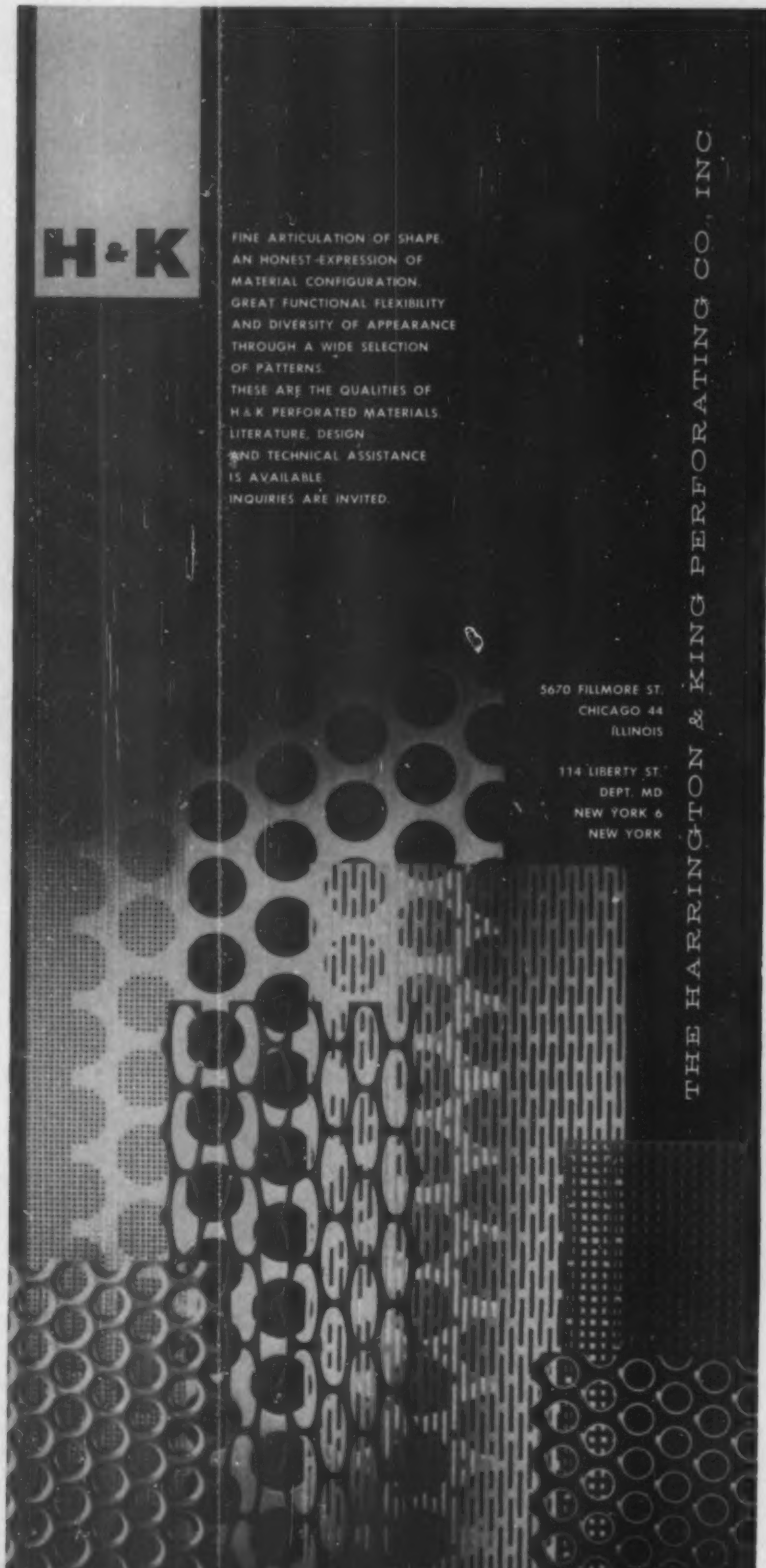

(Continued from Page 39)

Feb. 23-24—
Basic Engineering Refresher to be held in Milwaukee. Sponsor is the University of Wisconsin. Additional information is available from Engineering Institutes, 3030 Stadium, University of Wisconsin, Madison 6, Wis.

Feb. 27-28—
Automatic Production-Numerical Control Seminar to be held at the Statler Hilton Hotel, Cleveland. Sponsor is American Society of Tool and Manufacturing Engineers. Further information is available from Gilbert E. Seeley, Education Director, ASTME, 10700 Puritan Ave., Detroit 38, Mich.

Feb. 27-March 1—
Third Annual Symposium on Nondestructive Testing of Aircraft and Missile Components to be held at the Gunter Hotel, San Antonio, Texas. Sponsors are the South Texas Section of the Society for Nondestructive Testing Inc. and Southwest Research Institute. Additional information is available from Dr. Warren McGonnagle, General Chairman, Southwest Research Institute, Box 2296, San Antonio, Tex.

March 2—
Colloquium, "On Dual Numbers and Some of Their Applications to Kinematics," to be held at Northwestern University, Evanston, Ill. Additional information is available from Dept. of Mechanical Engineering, Technological Institute, Northwestern University, Evanston, Ill.

March 12-13—
Materials Research Conference to be held at North Carolina State College. Theme of the conference is bridging the gap between fundamental particulate concepts of solids and their engineering properties. Technical session topics include structure and imperfections in solids, aggregate structures, and continuum properties—stochastic concepts. Additional information is available from conference chairman, N. W. Conner, Director of Engineering Research, North Carolina State College, Raleigh, N. C.

Circle 222 on Page 19

It's all there, every detail sharp and clear, in RECORDAK precision 35mm microfilm images

There's more to these RECORDAK pictures than meets the eye!

RECORDAK precision 35mm microfilm images *more than meet DOD requirements*—give a minimum of 120 lines per mm resolution at 30-to-1 reduction ratio.

Look closely at some RECORDAK microfilm images in a film reader. See how every detail is sharp and clear . . . how the backgrounds are remarkably uniform, even though the pictures you're looking at were made from drawings and prints of every type and age.

How do these RECORDAK pictures come out so well?

First, the negatives are made on RECORDAK Micro-File Film with RECORDAK Precision Microfilming equipment. Carefully controlled exposure techniques assure uniform backgrounds and contrast. The exposed film then is developed, according to the most up-to-date scientific standards.

Your staff can easily be trained in the use of RECORDAK Micro-File equipment especially calibrated to produce images which meet DOD requirements.

This is important, for your success with an automated engineering drawing program depends *mainly* on the quality of the pictures you use, and on the quality of the prints you can make from them.

Free booklet goes into more details on precision microfilming available through Recordak or a Microfilming Dealer of Recordak.

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415 Madison Ave., New York 17, N.Y.

Send booklet describing RECORDAK Engineering Drawing System and name of nearest Microfilming Dealer of Recordak.

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originator of modern microfilming
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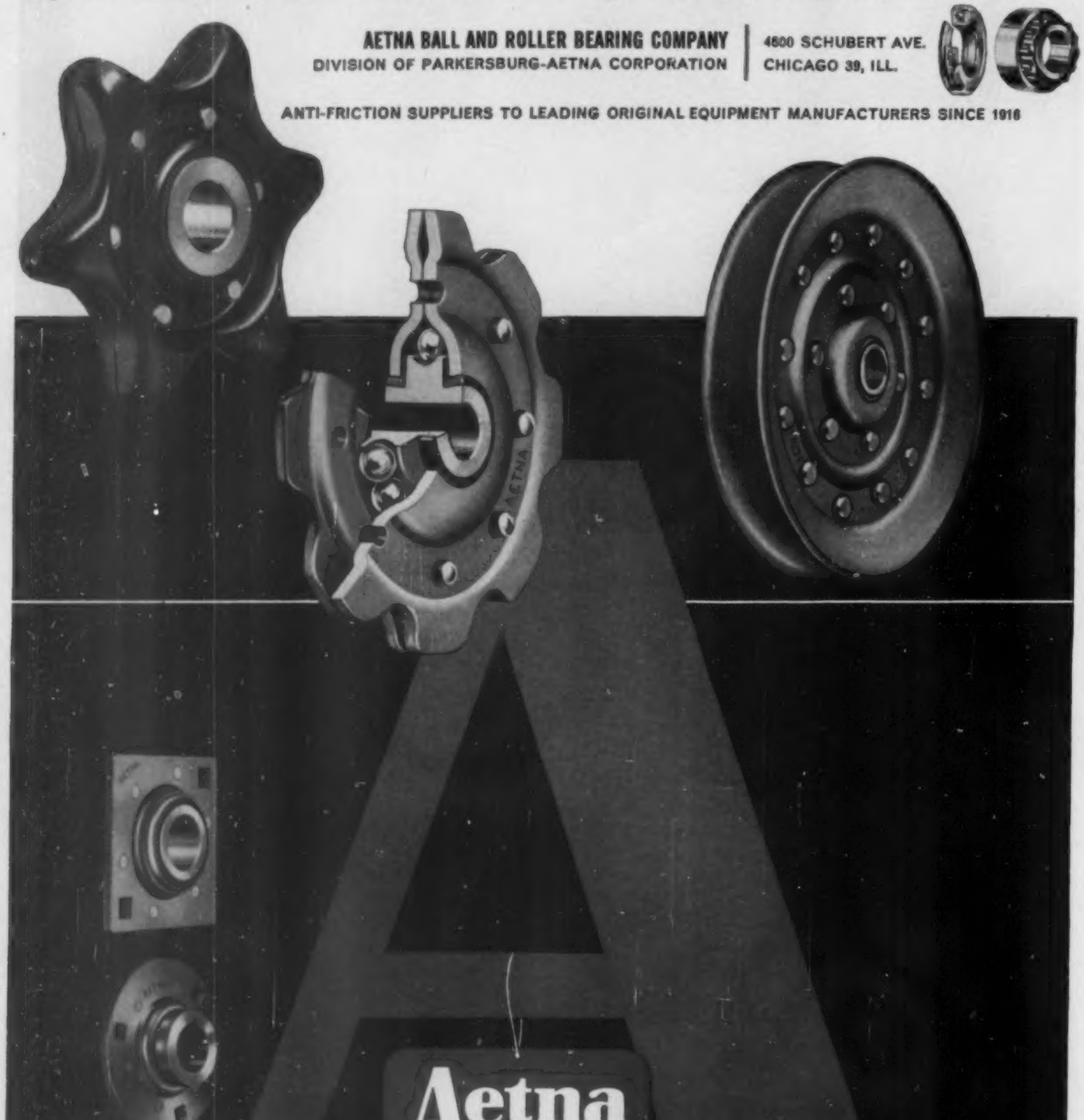
IN CANADA contact Recordak of Canada Ltd., Toronto

 Circle 223 on Page 19

IF YOU USE BELTS OR CHAINS—Long-life, low-cost Aetna AG Series Idlers will increase your drive efficiency. Units are simple in design. Extra large lubricant capacity and highly efficient seals provide dependable anti-friction performance. In operation they never need maintenance. And because they are completely prepackaged and prelubricated, they reduce your production cost, assembly cost, and stock handling problems. Investigate, also, the Aetna AG Series Adapter units for shaft support and other drive and conveying applications. All AG Bearings are available in a wide variety of sizes and configurations. Call your Aetna representative listed in your classified telephone directory for information, or write for General Catalog and Engineering Manual.

AETNA BALL AND ROLLER BEARING COMPANY
DIVISION OF PARKERSBURG-AETNA CORPORATION
4600 SCHUBERT AVE.
CHICAGO 39, ILL.

ANTI-FRICTION SUPPLIERS TO LEADING ORIGINAL EQUIPMENT MANUFACTURERS SINCE 1916



WHY PAY FOR METAL WASTE?

Here is how to cut costs on your next tube order... by eliminating excessive metal waste and unnecessary machining time.

NOW FOR THE FIRST TIME you can order the exact size tube O.D.'s you need from 2.25" to 50" with wall thicknesses from .25" to 8". An exclusive "first" in centrifugally spun tubing — the ACIPCO CERAM-SPUN® process* makes this revolutionary development possible.

YOU BUY WHAT YOU NEED... NO MORE. Furthermore, the cost of unwanted crop ends can be eliminated and tubes can be cast to specified lengths from 4 feet to 20 feet. Longer lengths are made by welding.

OTHER ADVANTAGES? ACIPCO's complete "under one roof" operations — including heat treating, machining and welding — save you the delays and excessive costs that often result in buying from multiple supply sources.

Let us tell you more about ACIPCO CERAM-SPUN® ... contact us today. ACIPCO STEEL PRODUCTS, Division of American Cast Iron Pipe Company, Birmingham 2, Alabama.

*Patent applied for

ACIPCO CERAM-SPUN®
STEEL TUBING

Circle 225 on Page 19

Louis Allis engineered systems include:

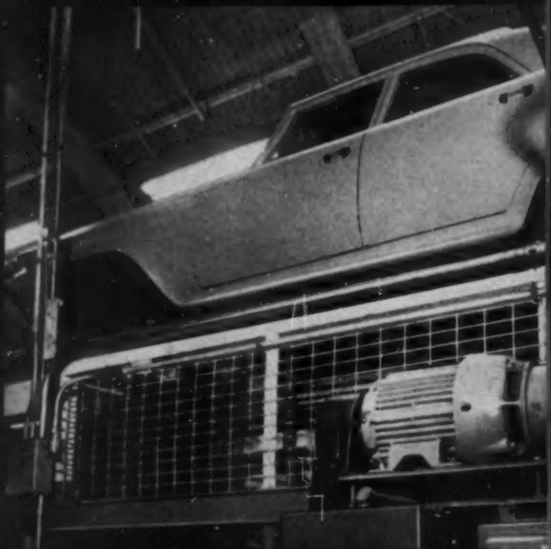
1 A Louis Allis drive powers this transfer table, shifts one body per minute into position for paint line after coming out of prime coat drying ovens.

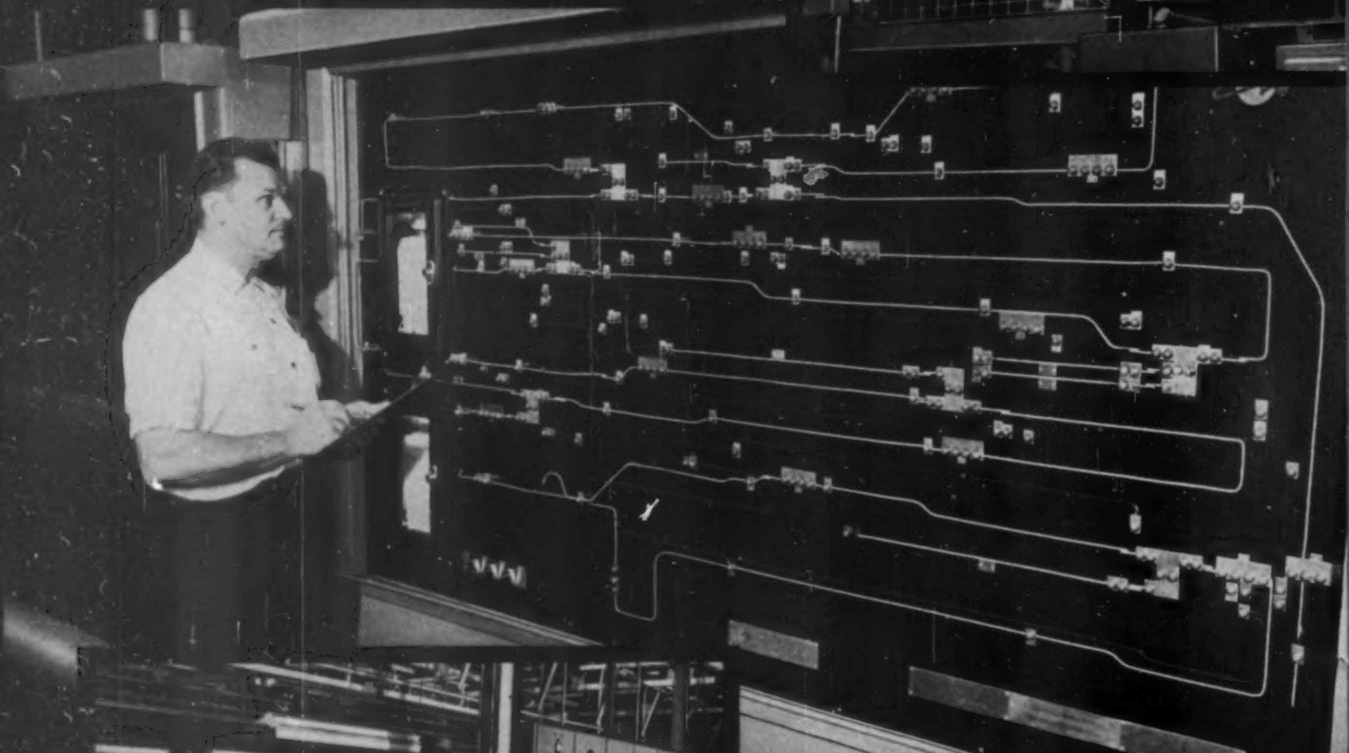
2 This 3 dimensional area control center monitors conveyor operations. Any type of production interruption is quickly revealed and identified by signal light indication. Recorders provide a permanent daily record of each conveyor's operation.

3 A bank of Louis Allis controllers regulate the drives powering the mating line where unitized body, stub frame engine assembly and running gear are assembled. Here, a Plymouth convertible comes off the assembly line.

4 Louis Allis controllers coordinate the intricate assembly of side-gate framing fixtures and underbody just prior to welding. Three components arrive from three different locations at precisely the same moment.

1. Automatic transfer station

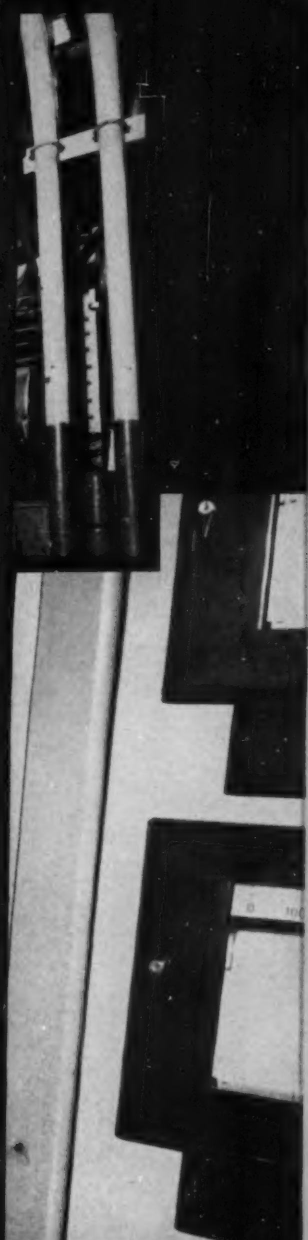


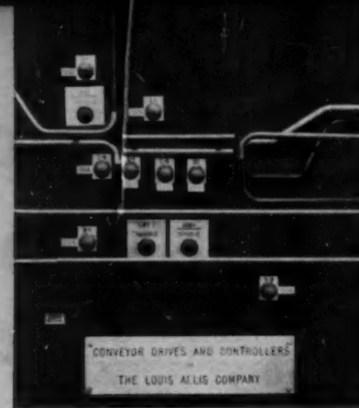


2. Area control center

3. Pre final assembly area

4. Initial body assembly





Engineering news from Louis Allis

LOUIS ALLIS engineered systems automate Chrysler assembly lines

An automobile assembly line is a materials handling complex of movement and synchronization. Feeder lines joining the main-line must deliver components on time — and in perfect synchronism. Still, the system must be flexible enough to accommodate speed changes when desired.

The Plymouth assembly plants in Detroit and St. Louis are models of this type of automation . . . and electrical components for the materials handling systems were custom-engineered by Louis Allis. L.A. systems engineers worked with Plymouth engineers to map the flow sequence. Louis Allis provided the adjustable speed drives and precision controls to operate the systems and supervised the installation. The result: integrated, automated systems that eliminate time loss, manpower waste, and excess materials handling costs.

Synchronized conveyors operate at pre-set speeds by following built-in master job-rate controllers. The system provides for automatic, position-perfect transfer of body components from one conveyor to another. A three-dimensional area control center monitors and records all conveyor operations.

If your plans call for automation, contact Louis Allis for systems engineering assistance — and single-source responsibility of drive and control design, manufacturing, and service. Call the Louis Allis District Office nearest you, or write to The Louis Allis Co., 459 E. Stewart St., Milwaukee 1, Wis. Ask for Bulletin 2900.

MANUFACTURER OF ELECTRIC MOTORS AND ADJUSTABLE SPEED DRIVES

LOUIS ALLIS

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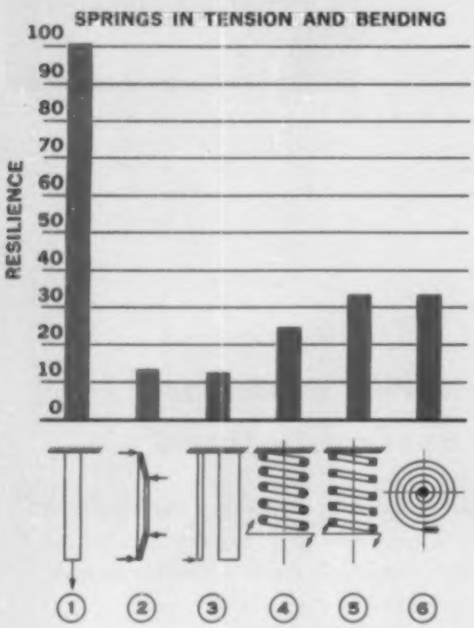
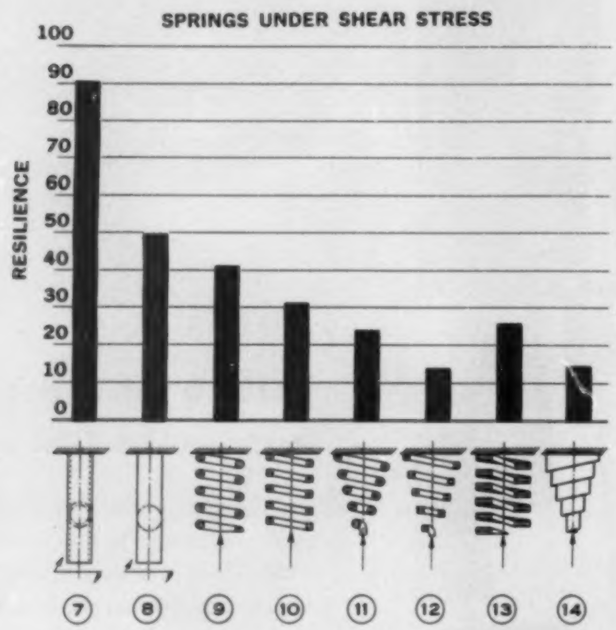
ASD-237

What Type of Spring to use ?

Here's a quick comparison of relative efficiencies





1. Tension bar
2. Belleville spring
3. Simple flat spring
4. Round wire torsion spring
5. Square wire torsion spring
6. Flat spiral spring
7. Thin wall torsion tube
8. Solid torsion rod
9. Round wire compression spring
10. Square wire compression spring
11. Round wire conical spring
12. Square wire conical spring
13. Rectangular wire compression spring
14. Volute spring

Relative efficiency of various types of springs can be compared on the basis of energy-absorbing capacity per cubic inch or per pound of metal in the active portion of the spring. The comparisons shown above assume springs are of metal of equal quality, able to withstand the same fibre stress. Obviously, other considerations may affect spring selection such as space available, material desired, atmospheric conditions, manufacturing cost, etc. So efficiency is often tempered by expediency.

If you're embarking on a project requiring springs, tap the knowledge and years of experience available from Associated Spring and its divisions at the locations listed below.

WRITE FOR BOOKLET
—*"How A.S.C. Solves Design and Production Problems of Springs and Spring-Like Things."*

6103R

Associated Spring Corporation

General Offices: Bristol, Connecticut

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F. N. Manross and Sons Division, Bristol, Conn.
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Raymond Manufacturing Division, Corry, Penna.
Cleveland Sales Office, Cleveland, Ohio
Chicago Sales Office, Chicago 46, Ill.
Ohio Division, Dayton, Ohio
B-G-R Division, Plymouth and Ann Arbor, Mich.
Gibson Division, Mattoon, Ill.
Milwaukee Division, Milwaukee, Wis.
Seaboard Pacific Division, Gardena, Calif.
Wallace Barnes Co., Ltd., Hamilton, Ont. and Montreal, Que.

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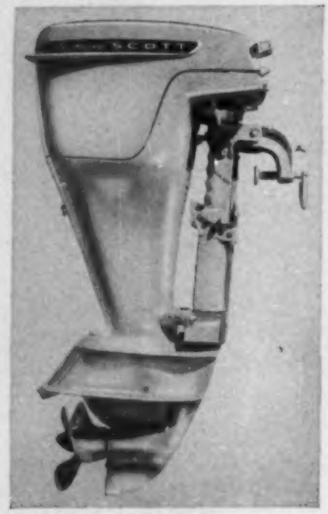
hodgman-bourke:
"there is no shortcut to good design"



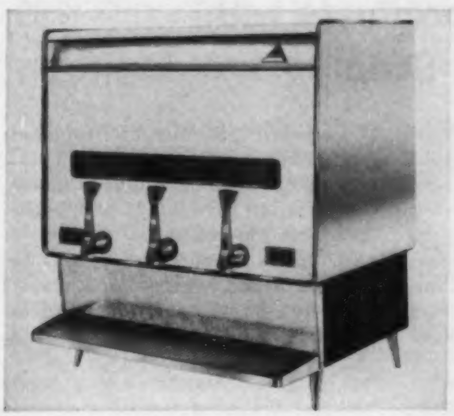
hodgman-bourke talk design

For two designers who founded their firm in 1955 with no clients, Clare Hodgman and Bob Bourke have come a long way. Their beginnings were modest, to say the least, but today they work on designs that range from trucks to cameras, vending machines to auto interiors, and many more. The secret of their success is really no secret at all: they simply design products that connote quality. To do this, a product should have what they call a "high index of desirability," i.e., convey thoughts of reliability and excellence of value.

Both Clare Hodgman and Bob Bourke have extensive background in automotive as well as in major appliance design, two areas where appearance and function are of supreme importance in the immediate success or failure of a product. Before forming their own firm, their combined experience included work with Sears Roebuck and Company, General Motors, Studebaker Corporation, and numerous products for English clients, including work for major European automobile producers.

Hodgman and Bourke feel there is no actual formula for design, because each product is different. There are, however, certain ground rules that apply to *any* design, and if the rules are followed, the ultimate product will have their "high index of desirability." First, they feel that if a manufacturer can make a product that is carefully planned and designed and show it at the point of sale, backed with a competent engineering and sales organization, there is no limit to how far he can go. Here material selection is vitally important. The best material must be selected—for economy, workability, strength, appearance and long life. Although there is always the chance that competition will come out with an improved version of that product, the best insurance against this is consistent intelligent research and product improvement.

The designer, they feel, is of equal



importance in both cases. It is up to him to design a saleable product in the first place, then keep that product on top through design. "Countless products are manufactured with little or no thought given to their improvement," says Bob Bourke. "We all know that they are sold in large quantities through the artificial stimulus of merchandising stunts, high frequency advertising, etc. This is short-range marketing and the manufacturer is in a vulnerable position." This product will lose, Bourke feels, to the well-designed, constantly improved product.

The designer himself must have many qualities. He must understand the patterns of business to gain the confidence of his client. He must be realistic. He must be a good merchandiser, thoroughly versed in technical matters, and he must have a healthy respect for the various limitations inherent in mass production. A man like this, working with an enlightened client, can move a product toward commercial success.

The designer must have a thorough working knowledge of his materials. In their work with a wide range of consumer and industrial products, Hodgman and Bourke must be able to select the material that gives them maximum workability, strength and a wide variety of types and grades from which to choose. Little wonder, then, that so many of their products are made of steel. They feel that "if steel were invented today, we would think it was a miracle material." In many Hodgman-Bourke designs, steel is used for its great strength (trucks, for instance). In others (like appliances) for its long-established sales appeal. Although not all of their products are designed in steel, like most designers they feel that steel is the number one material for strength, versatility, economy and variety.

USS TRADEMARK

United States Steel

Please direct inquiries to advertiser, mentioning MACHINE DESIGN

USS Design Steels: special solutions

Lower your costs and brighten your products with USS Bright Annealed Stainless Steel Strip

USS Bright Annealed Stainless Steel Strip with its desirable mirror finish requires less buffing in many applications and can save your money. In many cases, bright annealed Stainless Steel strip can be used with no costly buffing operation. U. S. Steel produces the strip by utilizing highly polished rolls which impart a smooth, dense surface on trim and molding stock that is carried through the annealing cycle by atmospherically controlling the furnace to give you, the product designer, a mirror finish and the full corrosion-resistant properties of Stainless Steel. Stainless Steel with its superior yield and impact strengths will resist dents, and scratching or cracking where other materials may fail.

In brief, USS Bright Annealed Strip offers a brighter finish and corrosion-resistant virtues of Stainless Steel. It can save you money in the products you design.

Drop us a note, and we will be pleased to send you a "production" sample. Write to United States Steel, Room 6435, 525 William Penn Place, Pittsburgh 30, Pa.

U. S. Steel first to develop rolled structural shapes from quenched and tempered alloy steels

Important weight and cost savings are possible with rolled structural shapes, made from quenched and tempered alloy steels now available from U. S. Steel. The new shapes are heat-treated to yield strengths as much as three times that of structural carbon steel. Furnished in standard I-beams, wide-flange, channels and angles, and in lengths up to 40 feet, the new shapes are produced from several U. S. Steel's best-known quenched and tempered alloy compositions, including "T-1" and "T-1" type A constructional alloy steels, 9% Nickel Steel for cryogenic applications, and HY-80 naval armor steel. Actually any alloy steel that derives its properties through heat treating can be made available.

These new rolled shapes will save the time and expense of cutting and welding plate material sections into structural shapes. Further information on these or our USS "T-1" plate steels is available from United States Steel, 525 William Penn Place, Pittsburgh 30, Pennsylvania.

Availability Quenched and Tempered standard structural shapes are available in the following shapes and sizes:

Beams: 8" to 16"	Wide-Flange Sections and Foot Weights*
Beams: 6" to 12" inclusive	American Standard Sections and Foot Weights*
Channels: 6" to 15" inclusive	American Standard Sections and Foot Weights*
Equal Angles: 3" to 8" inclusive	Standard Sections*
Unequal Angles: 3½" x 3" to 8" x 6" inclusive	Standard Sections*

Maximum Length 40' for all sections

*See our booklet, "USS Shapes & Plates," ADUCO-27001

Mechanical Properties of Quenched and Tempered Alloy and Armor Steel Structural Shapes

	Yield Strength psi	Tensile Strength psi	Elong. in 2", % Min.	Reduction of Area % Min.	Longitudinal Full-size Charpy Impact (when spec.)	
					Keyhole	V-notch
"T-1" Steel 2½" to ⅜"	100,000 (Min.)	115,000/ 140,000	18	55[1]	15 ft.-lbs. @ —50F	30 ft.-lbs. @ +10F
"T-1" type A 1" to ⅛"	100,000 (Min.)	115,000/ 140,000	18	55[1]	15 ft.-lbs. @ —50F	....
Grade A 9% Nickel	60,000 (Min.)	90,000 (Min.)	22% Min.	...	15 ft.-lbs. @ —320F	20 ft.-lbs. @ —320F
Grade B 9% Nickel	65,000 (Min.)	95,000 (Min.)	20% Min.			
HY-80 ¼" to 2" Incl.	80,000 100,000[2]	....	19[3]	...	....	70 ft.-lbs. @ —120F

(1) ⅝" and under—45% Min.
(2) ½" and over, yield strength range is 80/95,000 psi
(3) ½" to 2" inclusive, elongation 20% Min.

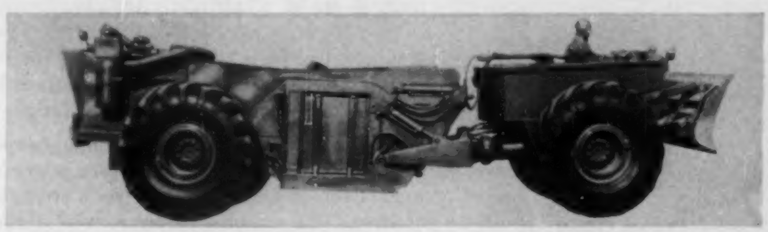
This mark tells you a product is made of modern, dependable Steel.

for special problems

(USS) Par-Ten High Strength Steel makes bumpers stronger, better-looking, cuts costs

Bumpers of USS PAR-TEN High Strength Steel have 40% greater strength than ordinary carbon steel bumpers. In addition, they have high resistance to impact and a surface that takes an excellent chrome finish. With PAR-TEN Steel at a typical yield point of 45,000 psi, bumper weight can be reduced by as much as 20%. USS PAR-TEN High Strength Steel was developed especially for bumpers, bumper guards and similar high-finish uses. It keeps superior surface characteristics even after severe grinding. It gives a gleaming chrome finish, yet provides increased resistance to denting and impact. Detailed information is available. Write United States Steel, 525 William Penn Place, Pittsburgh 30, Pa.

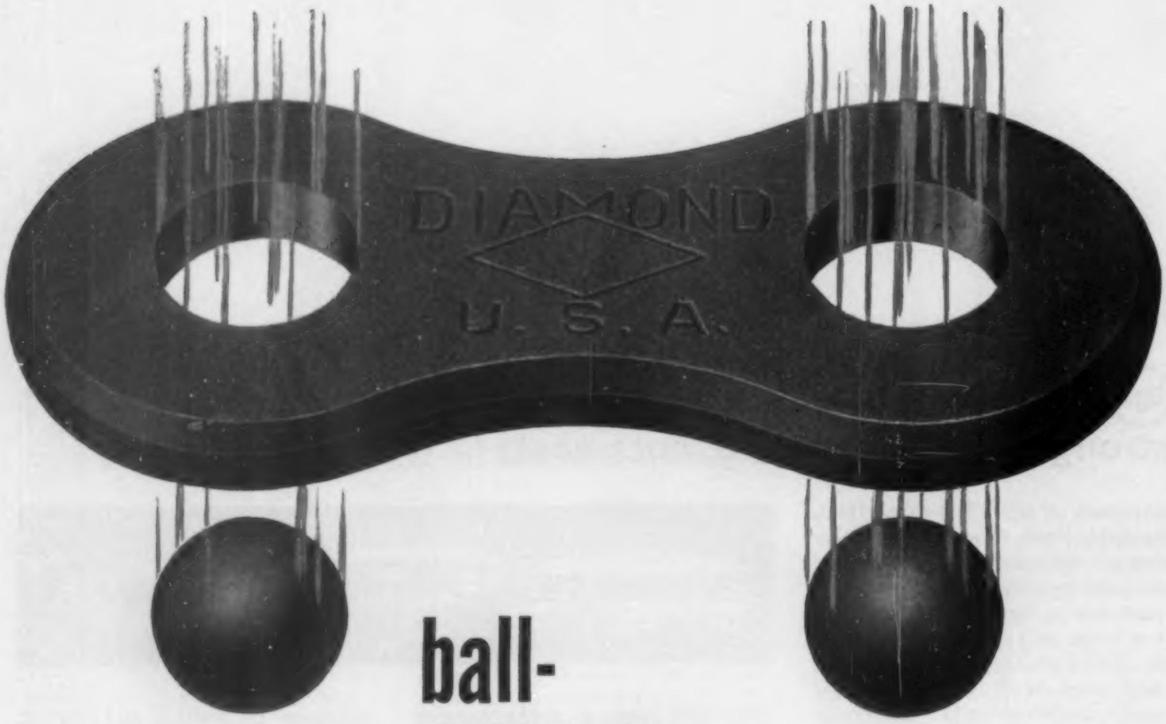
This tractor flies in a plane, parachutes to earth



This 250 HP steel tractor-scraper-dozer can be flown in a C-130 aircraft and parachuted into a combat area, ready to operate. It can transport 10 cubic yards of earth at 35 mph. It owes its light weight and great structural strength to USS "T-1" Constructional Alloy Steel and USS MAN-TEN High Strength Steel. Three and a half tons of deadweight were saved by designing the yoke, dozer arms, front and rear axle housings and basic bowl structure with USS "T-1" Steel. MAN-TEN Steel is used in the bowl, side plates and dozer blade. The complete unit is built tough and strong with 7,500 lbs. of USS "T-1" and MAN-TEN Steels. For other military vehicles, U. S. Steel makes extremely tough rolled armor plate, in addition to a complete line of weldable, formable high strength and alloy steels. For more information on any of these, write United States Steel, 525 William Penn Place, Pittsburgh 30, Pa. USS, "T-1," PAR-TEN, and MAN-TEN are registered trademarks.

USS TRADEMARK **United States Steel**

Please direct inquiries to advertiser, mentioning MACHINE DESIGN



ball-drifted...

for greater fatigue resistance!

A PATENTED DIAMOND ROLLER CHAIN PROCESS THAT ASSURES FASTER, LONGER, MORE EFFICIENT OPERATION FOR YOUR EQUIPMENT

Forcing hardened steel balls through linkplate pitch holes enables DIAMOND Roller Chain to transmit greater loads at higher speeds . . . over longer periods of time without critical metal fatigue!

Stress tends to concentrate at notches and sharp corners—hence the notch effect of tool marks and tearing from punching can lead to fatigue failure at loads even less than 15% of chain strength. DIAMOND, with its patented "ball drifting" process, cold works pitch holes of linkplates to an accurate diameter with surfaces of *mirror-like finish*. This process creates increased resistance to fatigue and provides maximum press fit and holding power—greater structural rigidity when assembled with pins and bushings.

For power transmission, conveying or synchronization, always specify DIAMOND Roller Chain.

DIAMOND CHAIN COMPANY, INC.
A Subsidiary of American Steel Foundries
Dept. 435 • 402 Kentucky Ave., Indianapolis 7, Ind.

Offices and Distributors in All Principal Cities

DIAMOND ROLLER CHAINS ®

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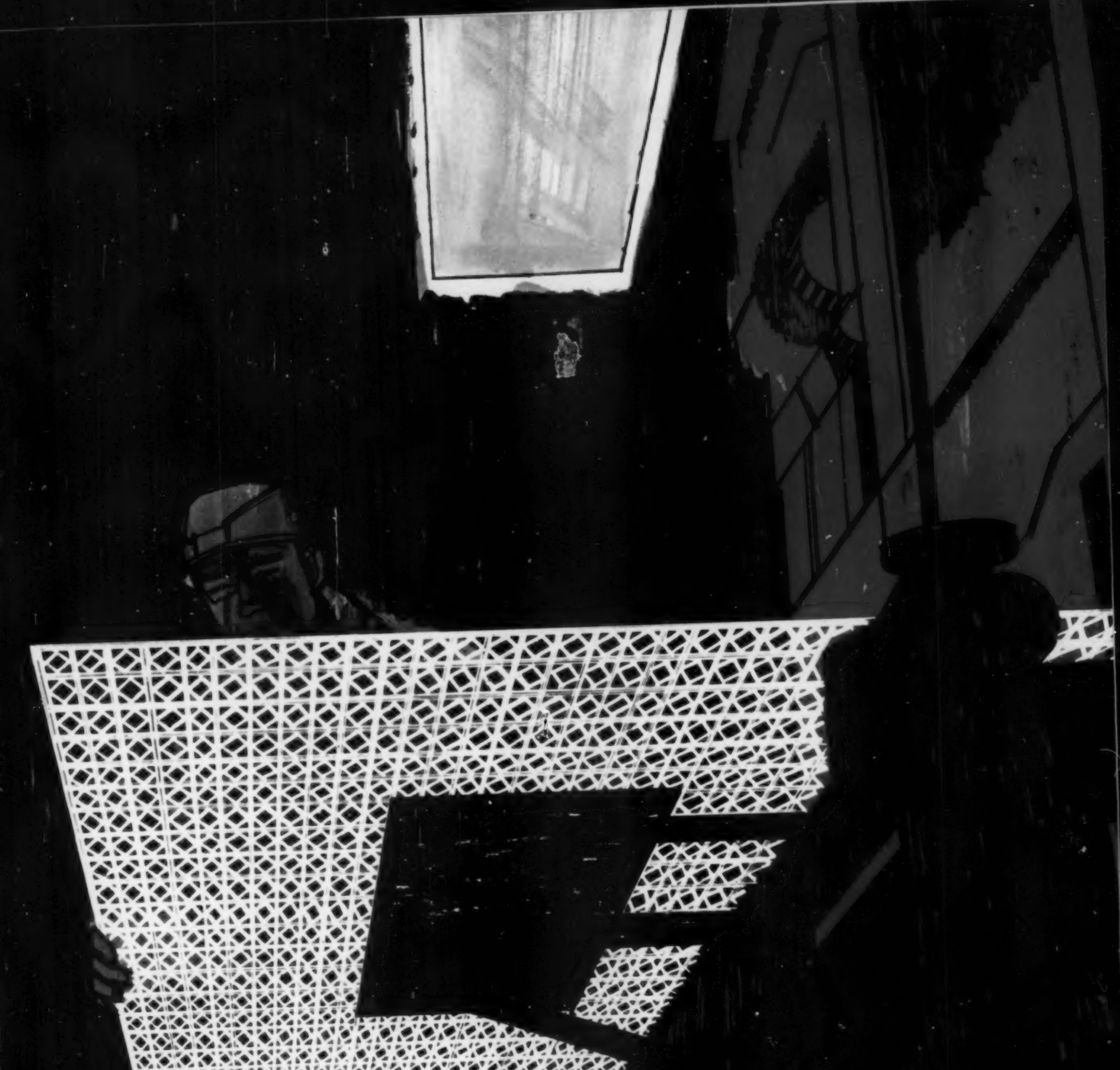

N-S Perforated Metal...

Beautiful, functional Cross Perforated Metals—clean-walled, burr-less holes—produced by precision, multiple-punch tools. Perforated steel or aluminum gives you open area or ventilation, the beauty of ornamental designs or the utility of round hole patterns, the formability of sheets and coils. Stocked by leading distributors everywhere.

NATIONAL-STANDARD COMPANY
Cross Perforated Metals Plant
Carbondale, Pennsylvania

HOW TO MEASURE YOUR DIE CASTER...

One thing is sure... you don't evaluate your die caster on the price/weight ratio of a single piece of metal, but rather on continuing, accurate and dependable service. That's why we say you get better die casting value from Doehler-Jarvis. Doehler-Jarvis has been producing and finishing castings for over fifty years for all segments of the metal-working industry. Doehler-Jarvis is fully integrated. Designs and makes its own dies... is equipped with casting machines of all sizes and capabilities . . . can trim, machine, finish and subassemble to meet your specific needs. Doehler-Jarvis die casts in the widest range of alloys...zinc, aluminum, magnesium and copper. Doehler-Jarvis delivers on its own fleet of trucks. You get your die castings where you want them, when you want them. You keep your production lines moving and free the money formerly buried in unwieldy inventories. Measure Doehler-Jarvis against any die caster in the business. Then permit us to figure costs when you are in the market for metal parts. Write or call the Doehler-Jarvis office near you.

DOEHLER-JARVIS
DIVISION OF NATIONAL LEAD COMPANY

GENERAL OFFICES: TOLEDO 1, OHIO. PLANTS AND SALES OFFICES: TOLEDO, OHIO; GRAND RAPIDS, MICHIGAN; POTTSTOWN, PENNSYLVANIA; BATAVIA, NEW YORK. IN CANADA: BARBER DIE CASTING CO., LTD., HAMILTON, ONTARIO. IN BRAZIL: INDUSTRIAS DOEHLER DO BRAZIL, S. A., SAO BERNARDO DO CAMPO, SAO PAULO. IN ARGENTINA: DOEHLER ARGENTINA, S. A., BUENOS AIRES. IN GREAT BRITAIN: METAL CASTINGS-DOEHLER, LTD., WORCESTER, ENGLAND.

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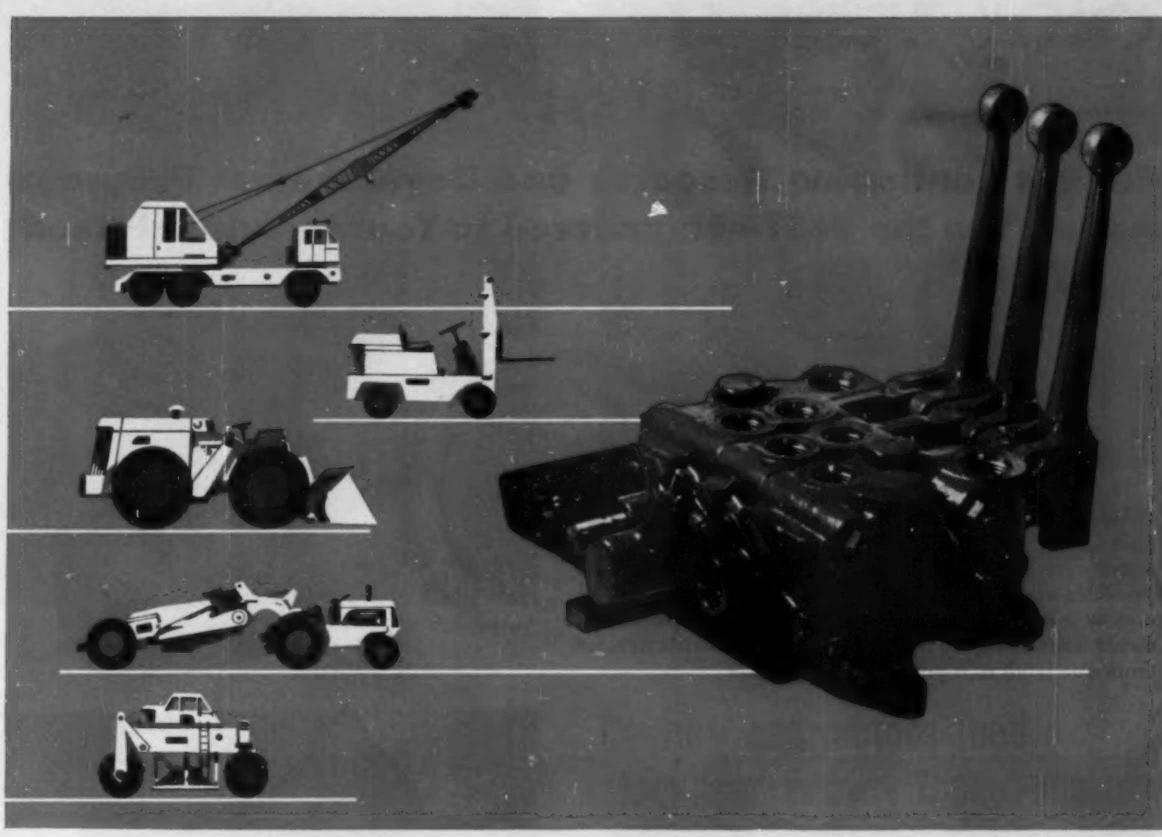
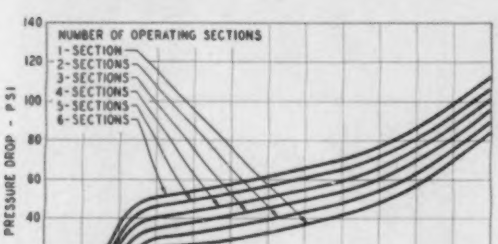


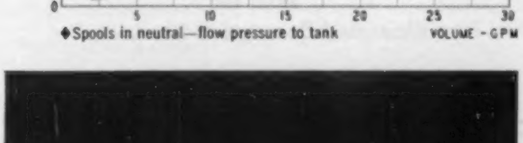
FOR BETTER, SMOOTHER LOAD CONTROL . . .

VICKERS DIRECTIONAL VALVES OUTPERFORM THE REST

Pressure Drop Curves◆



◆Spools in neutral—flow pressure to tank



Feather control of the load and the capacity to do more work over the entire 0 to 2500 psi operating range are yours with the new Vickers CM11 Series multiple unit valves. Not only will they handle the needs of today's most modern mobile equipment but they also have the built-in capacity to meet all foreseeable future needs.

For an indication of how these ultra-compact valves could improve performance of your equipment, check the pressure drop curves. Then, compare them with pressure drops on control valves you are now using. Reduced pressure drop means less horsepower wasted in the valve—more work capacity on every type of mobile equipment. This reduced pressure drop is the result of Vickers new, patented partial-flow by-pass feature.

Improved metering to eliminate jerkiness when raising or lowering loads . . . greater installation and service flexibility with Vickers-pioneered sectional design . . . choice of spool designs to meet wide range of operational needs . . . new enlarged porting . . . all are described in detail in Bulletin M-5112. Write today to Vickers Incorporated, Detroit 32, Michigan.

VICKERS®
DIVISION OF SPERRY RAND CORPORATION

1005

Circle 233 on Page 19

Can You Use BETTER Gray Iron Castings?

Eaton's Continuing Research and Development Programs Assure You the BEST—Engineered to Your Individual Needs

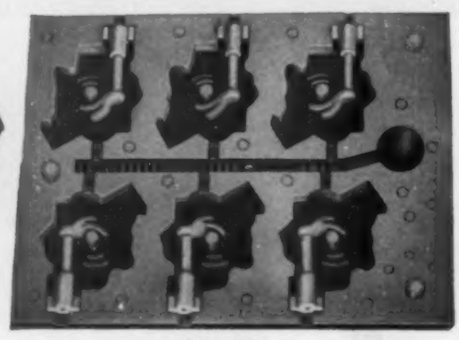
EATON PERMANENT MOLDING

Because of the denser, non-porous, homogeneous structure, Eaton Permanent Mold Castings meet critical quality requirements. The finer dispersion of graphite provides a better material where free machinability and accuracy are essential in critical machining operations. Eaton annealed gray iron castings are available in sizes from one tenth of a pound to fifty pounds.

EATON SHELL CORING

The Eaton process of Shell Coring in permanent mold and shell molded castings provides better internal surface finish and higher dimensional accuracy. Where more than ordinary quality and control of contour are required, the Eaton process offers distinct design advantages and greater uniformity in intricately cored sections.

EATON SHELL MOLDING

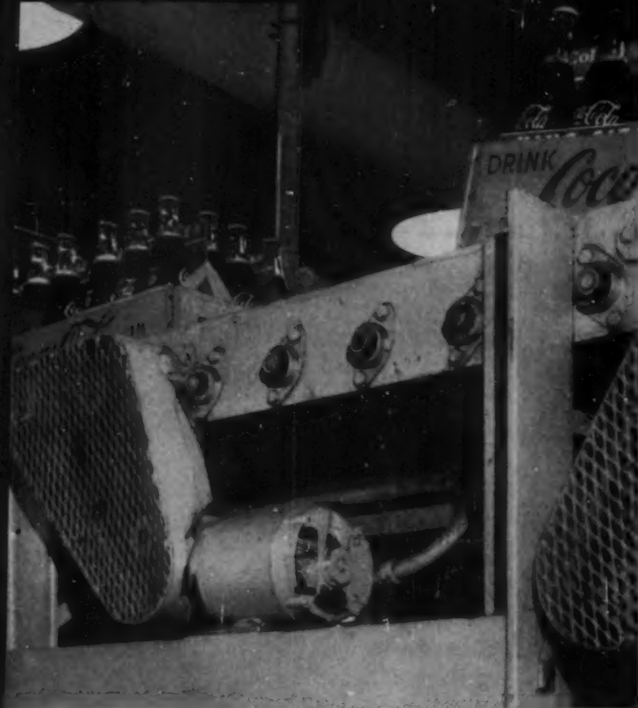


Eaton Shell Molding provides more closely controlled metallurgy and hardness for applications requiring pearlitic structures, close dimensional control, and complex designs and contours. Eaton Shell Mold Castings require less machining and finishing, with resulting savings in material, tooling, and shipping.

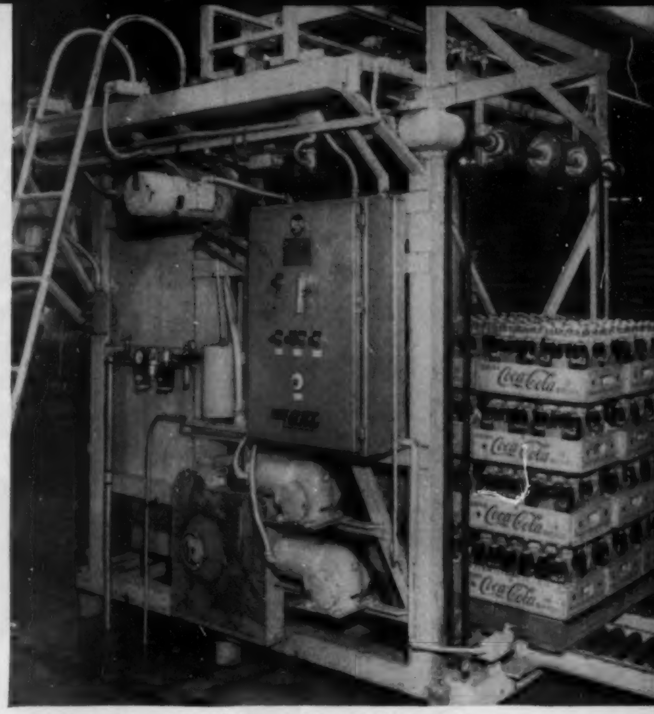
Send for Illustrated Descriptive Literature

EATON

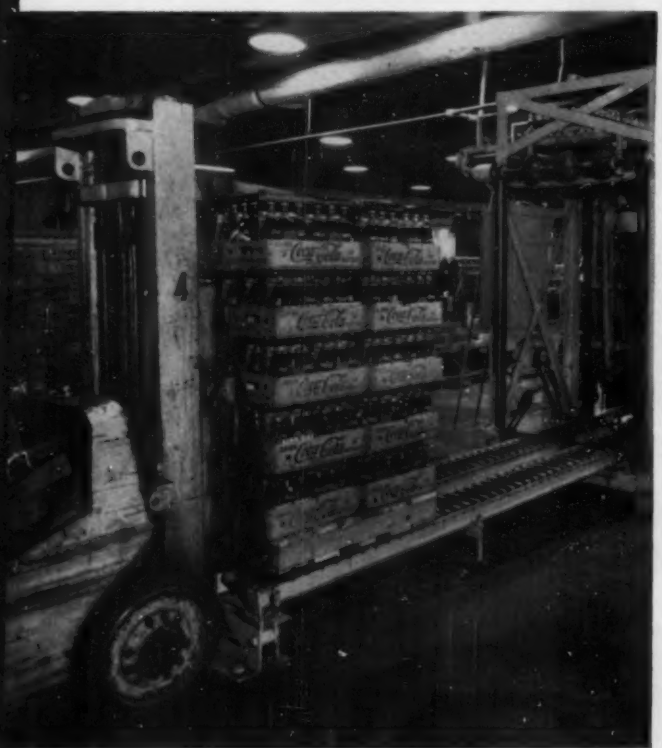
FOUNDRY DIVISION
MANUFACTURING COMPANY
VASSAR, MICHIGAN



1 Century's compact IR 48-frame gearmotor driving live roll conveyor to the top of pallet loader.



2 A Century 1R64 SC64 gearmotor with brake (in upper left of picture) raises and lowers pallets from empty pallet conveyor to loaded pallet conveyor.



3 Loaded pallets being picked up by lift truck. Century 1R66 SC66, ¾ horsepower gearmotors drive empty and loaded pallet conveyors.

Century gearmotors load, stack and convey thousands of soft drinks per day

Century Electric's single-reduction, right-angle gearmotors are built right into the versatile pallet loader shown here. Thousands of bottles of soft drinks a day are conveyed, stacked, loaded onto pallets and conveyed to fork lift trucks by Century's gearmotors.

Century gearmotors, with silicon bronze worm gears and hardened high-grade steel worms, are designed and built to withstand sudden shocks and overloads in applications such as this pallet loader. Motor shafts are not affected by operational strains because mounting feet are an integral part of the housing (except the IR 48-frame). Also, motor shafts are carried on ball bearings and output shafts run in tapered roller bearings to withstand sudden shocks.

All-angle oiling design assures complete lubrication. Worms or worm gears dip into oil, no matter how the gearmotors are mounted.

The gearhead on the IR 48-frame gearmotor (Picture No. 1) can be assembled in four different positions in relation to the motor, and the motor can be mounted at any angle. The new 1R 48-frame gearmotor is also very compact. With it you can reduce the weight of your product by as much as 20 pounds.

For more information about Century's complete gearmotor line from ⅛ to 125 horsepower, call your nearest Century Sales Office.

CENTURY ELECTRIC COMPANY

St. Louis 3, Missouri *Offices and Stock Points in Principal Cities*

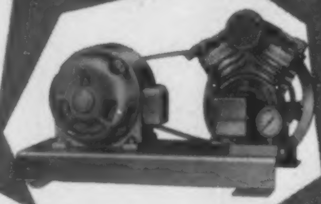
Circle 235 on Page 19

Century

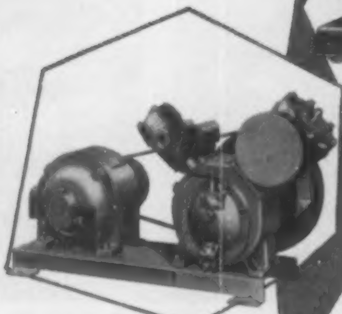
60-2

Pick your Pressure for any Purpose

FROM THESE AIR-COOLED AIR COMPRESSORS

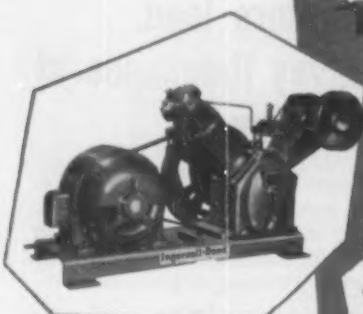


Ingersoll-Rand Model B
Single-stage ¼ hp
10 to 150 psig



Ingersoll-Rand Model 7TX
Two-stage 7½ hp, baseplate mounted
100 to 250 psig

Ingersoll-Rand Model 7T2
10 hp, up to 500 psig operation



Ingersoll-Rand Model 41X5
5 hp, pressure rating to 1000 psig

Ingersoll-Rand Model 4R[illegible]
3000 psig unit, also portable mounting or bare compressor available

Ingersoll-Rand Model 6R80
portable compressor
New 80 cfm, 6000 psig unit
complete or base unit available

These are a few of the Ingersoll-Rand air-cooled air and gas compressors which have won approval on such installations as general support equipment for military and commercial aircraft and missiles, naval and maritime service, air blast circuit breakers, air starting of engines, test stands for valves, accumulator service; in fact, any service requiring a dependable, adequate source of compressed air.

Whatever your compressed air requirements, there's an Ingersoll-Rand compressor that will meet your needs exactly. Just give us your capacity and pressure requirements and we'll help you select the compressor to meet your needs.

WORLD'S MOST COMPLETE LINE OF AIR COMPRESSORS TO 125,000 PSIG

Ingersoll-Rand

11 Broadway, New York 4, N. Y.

268A3

Circle 236 on Page 19

Circle 237 on Page 19→

When should you use Mercury-Wetted Contact Relays?

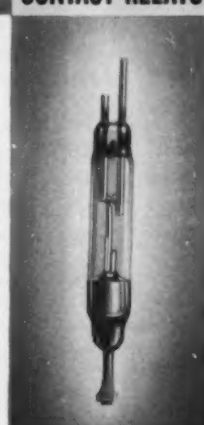
An unusual combination of advantages found only in mercury-wetted relays has led many design engineers to specify them for tough switching jobs. Here are but 3 typical characteristics of our JM series:

RELIABILITY. Sealed-in-glass mercury contacts are renewed with every operation. Won't pit or weld. Make or break is positive . . . every time. No bounce, no chatter. Signals ranging from a few micro amps to 5 amps are switched with singular consistency.

LONG LIFE. Think in terms of *billions* of operations when considering JM series relays. Proper application, of course, is a requisite.

SPEED. Operate time is just less than 3 milliseconds using 2 watts of power. Release time is about 3.2 milliseconds. Thus, relays can be driven 100 times per second.

If your project calls for exceptional relay performance, perhaps the answer lies in our JM Mercury-Wetted contact relay.



JM SERIES ENGINEERING DATA

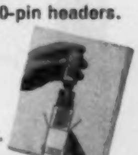
Contact Rating:
5 amperes maximum
500 volt maximum
250 volt-amp max. with required contact protection.

Contact Configuration:
Each capsule SPDT. Combination of capsules in one enclosure can form DPDT, 3PDT, 4PDT. (All Form D.)

Terminals:
Plug-in or hook solder; 8, 11, 14, or 20-pin headers.

Coil Resistance:
2 to 58,000 ohms.

More information?
Write today for free catalogue.



P&B STANDARD RELAYS ARE AVAILABLE AT YOUR LOCAL ELECTRONIC PARTS DISTRIBUTOR

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DIVISION OF AMERICAN MACHINE & FOUNDRY COMPANY • PRINCETON, INDIANA
IN CANADA: POTTER & BRUMFIELD, DIVISION OF AMF CANADA LIMITED, GUELPH, ONTARIO

Normally you think of Globe as the prime source for precision miniature military motors. Now we are ready to fill the need for high quality in commercial and industrial products too. Each of these Globe **commercial motors** combines the performance usually found only in MIL spec motors, corresponding weight and size reduction, and at a price comparable to ordinary motors of larger size.

The breakthrough is in new design and production techniques that permit the use of quality materials, yet reduce the number of parts and operations. The five frame sizes below (more are coming) can be furnished in a.c. and d.c., wound and modified to your requirements. We are happy to help solve your motor problem. We also can supply integral gear heads to give the exact speed-torque you need. Globe motors are for products that need to be compact, dependable and rugged. Most important, they help you make your product more salable.

For Bulletin CMB, or a prototype, write or telephone Yale Holt, Sales Manager, Globe Industries, Inc., 1784 Stanley Avenue, Dayton 4, Ohio. Telephone 222-3741.

GLOBE INDUSTRIES, INC.

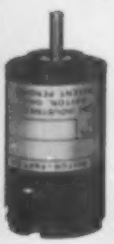
GLOBE

PRECISION MINIATURE MOTORS, GEARMOTORS, TIMERS, ACTUATORS, CLUTCHES, BLOWERS, MOTORIZED DEVICES

COMMERCIAL INDUSTRIAL MOTORS / NEW SMALL

TYPE SMP, 6 v.d.c., 3/4" dia. x 1 5/8" long. 0.3 oz. in. torque at 8,000 rpm.

Circle 238 on Page 19



TYPE CMC, 110 v.a.c., 1 11/64" dia. x 2 11/32" long. Hysteresis-synchronous. 1800 or 3600 rpm. 0.75 oz. in. torque at synchronous speed.

Circle 239 on Page 19

TYPE MMP, 12 v.d.c., 1 3/8" dia. x 1 3/4" long. 0.9 oz. in torque at 5,500 rpm.

Circle 240 on Page 19

TYPE CFC, 115 v.a.c., 2 11/16" dia. x 2 7/8" long. Induction or hysteresis-synchronous. 2 oz. in. torque at 1800 or 3600 rpm. synchronous.

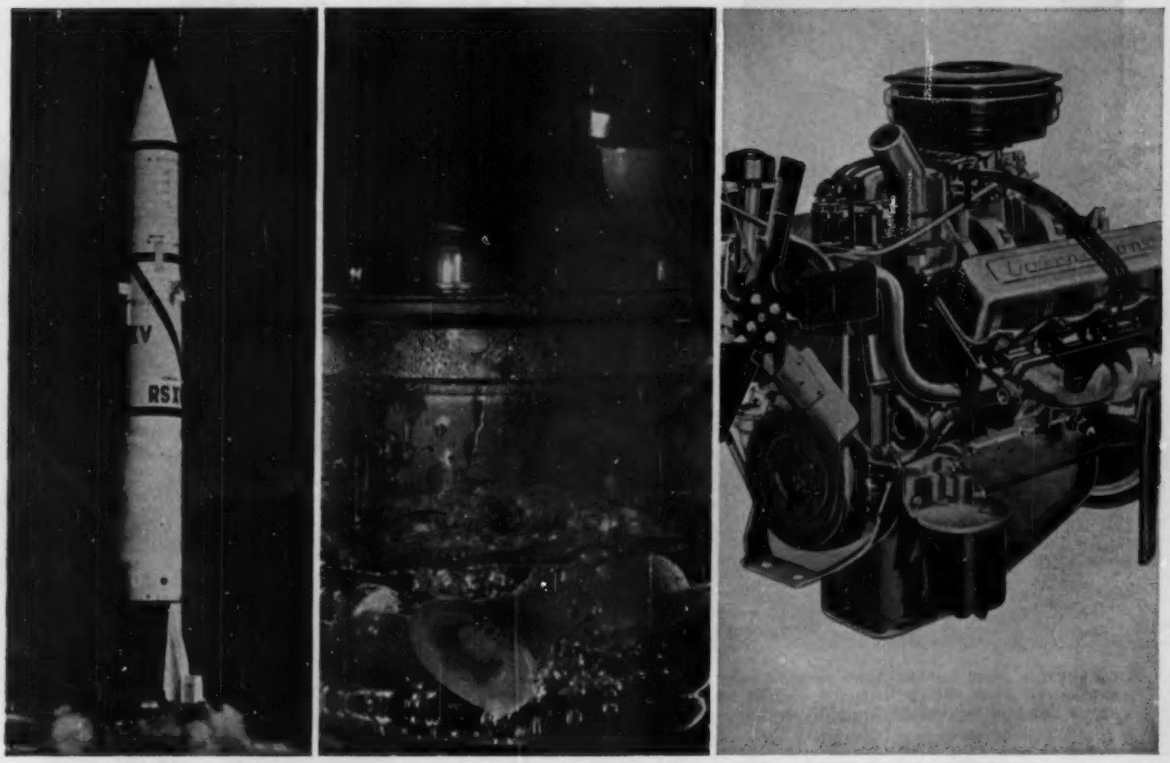
Circle 241 on Page 19

TYPE CLC, 115, v.a.c., 2 15/16" dia. x 3 11/16" long. Induction or hysteresis-synchronous. 13 oz. in. torque at 1800 or 3600 rpm. synchronous.

Circle 242 on Page 19

SILICONE NEWS from Dow Corning

Frozen...boiled...battered



Silastic — the off-the-shelf rubber for designers with uncommon problems

LOX chilled but flexible. Silastic®, the Dow Corning silicone rubber, has been used for between-stage gaskets on missiles fueled with liquid oxygen. That's because Silastic stays rubbery to temperatures as low as —130 F, resists compression set and the adverse effects of prolonged storage.

Boiled to be bitten. Baby bottle nipples made of Silastic withstand repeated boiling and biting. There's no cracking or melting. Since Silastic withstands temperatures of 500 F, boiling water is like a baby's bath. Then, too, chewing and flexing after repeated thermal cycling has little effect on Silastic's strength or rubberiness.

Battered and bruised. The front and rear crankshaft seals of this rugged truck V-8 are made of Silastic. That's because Silastic stays rubbery, maintains a positive tight seal capable of taking a beating even when oil temperatures reach 270 — 280 F and crankshaft speeds reach 4000 rpm. For a tough elastomer with excellent resistance to engine oil, what better material than Silastic?

Silastic can be custom-engineered by most rubber companies into parts to meet your specs. These fabricators also carry such components as o-rings, gaskets, tubing and similar commercial items in various sizes and shapes as factory stock.

For full information and list of rubber companies offering Silastic, write to Dept. 6924, Dow Corning Corporation, Midland, Michigan.

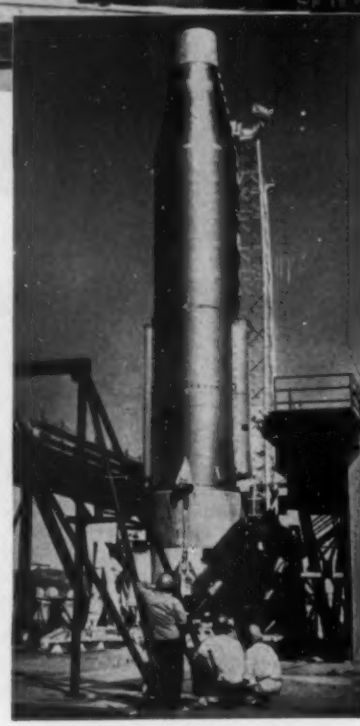
first in silicones

Dow Corning

Circle 243 on Page 19

CONVAIR ERECTOR-LAUNCHERS RELY ON POWERFUL PHILADELPHIA GEAR DRIVES

Atlas ICBM in stored position. Arrow points to heavy duty Philadelphia Gear hoist drive, which quickly erects missile to launch position for skyward voyage. Erector-launcher designed and built by Convair (Astronautics) Division of General Dynamics Corporation.



Atlas can now lie low till needed . . . new hoisting mechanism eliminates massive gantry towers

The Air Force has equipped itself with a new missile hoist mechanism which is both speedy and powerful. These two requirements plus ultra-reliability have qualified Philadelphia Gear Drives for the moments-notice job of erecting Atlas to launch position. The "Big Punch" is now stored horizontally. These erector-launchers are now operational at Atlas ICBM complexes at Warren Air Force Base, Wyoming.

The Philadelphia Gear Drive is a standard, all-steel, parallel shaft reducer. Output torque is 634,000 lb/inches at 7½ rpm, on low speed shaft; 1,250,000 lb/inches under emergency conditions; ratio—234:1. All units are load tested to 300% of normal rating.

Standard Philadelphia heavy-duty drives are right at home in any application that demands an extra margin of reliability. Our engineering specialists in all kinds of power transmission problems have made sure Philadelphia Gear equipment has more than kept the pace to help America keep the peace. To see what can be done in gearing today, write for our catalog "Philadelphia Parallel Shaft Speed Reducers," No. H-58.

AGMA MEMBER

philadelphia gear drives

PHILADELPHIA GEAR CORPORATION

King of Prussia (Suburban Philadelphia), Pennsylvania

4 factors to consider in evaluating gas turbine controls

1. Consider design know-how. Bendix employs the systems approach. And we have the demonstrated ability to design and tailor systems that will meet individual needs of all small gas turbines.

2. Consider practical experience. Bendix pioneered in developing fuel metering systems. Already produced: over 1¼ million aircraft carburetors, 34,000 fuel injection systems, and 97,000 gas turbine control systems and components.

3. Consider support facilities. Bendix maintains complete facilities for foundry and heat treat, engine test, qualification test, and development and environmental test, to name a few.

4. Consider production capabilities. Over 3,000 modern machine tools and 500 experienced engineers and technicians. 2,200,000 square feet of manufacturing area.

Consider the source, and you'll specify Bendix.
Write Sales Manager, Engine Equipment,
South Bend 20, Indiana

Bendix Products
Aerospace Division

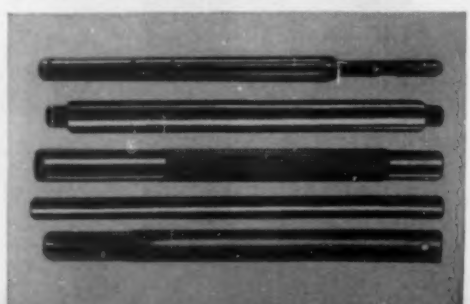
THE Bendix CORPORATION

Circle 245 on Page 19

REPUBLIC STEEL...

PROBLEM-SOLVING KNOW-HOW AND EXPERIENCE have made Republic a leader in custom production of Fastener and Formed Parts "Specials." Whenever standard fasteners can't do the job, you'll save time and money by contacting Republic. Write for data on Republic design, engineering, and production services. *Circle 246 on Page 19*

TRIM COLD FINISHED BAR COSTS. Republic's CENTURY SERIES offers five grades of high-strength, stress-relieved, cold finished bars, each with a minimum yield strength of 100,000 psi. For highly machined parts, use C-1144. Moderately machined parts—C-1140 or C-1151. For parts where machinability is a minor factor—C-1050 or C-1045. Send for complete data. *Circle 247 on Page 19*



Strong, Modern, Dependable

World's Largest Producer of SPECIALTY WELDED TUBING

Challenge us to come up with a solution to your toughest tubing applications.

We will produce the best possible answer drawn from Republic's full line of quality welded steel tubing and more than 50 years of applied engineering experience.

This claim is made with confidence. Our customers regularly hand us their tubing problems, and the results have provided mutual satisfaction.

Manufactured at the Steel and Tubes Division, Republic Tubing is welded by the ELECTRUNITE® process—a continuous electric weld method which unites the wall under pressure without foreign or extra metal. Among other advantages, this process assures uniformity of wall thickness, strength, ductility, and concentricity.

Republic, the pioneer in this improved welding process, was also the first to provide a nondestructive electronic production method of testing tubing used for critical pressure applications. This is known to the trade as FARROWTEST®.

Next time you have a tubing application or problem, take advantage of Republic's prompt delivery, engineering services, and complete range of carbon and stainless steels for mechanical, structural, and pressure uses.

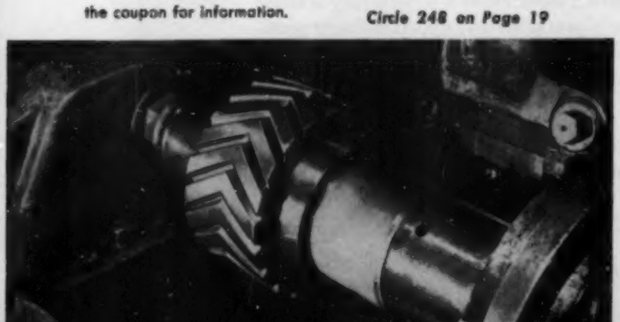
Call your nearest Steel and Tubes representative or contact us direct.

REPUBLIC STEEL

REPUBLIC HAS THE FEEL FOR MODERN STEEL

FOR ADDED MACHINABILITY, consider Republic Cold Drawn Leaded Alloy Steels. Leading producers of gears use Republic Leaded Alloy Steel in the manufacture of heavy-duty herringbone gears. Addition of lead increases machinability as much as 25%. Heat treating assures adequate hardness and toughness. Cost-reducing Republic Alloys are available in almost every standard analysis and many specials. Mail the coupon for information.

Circle 248 on Page 19



Check this listing of Republic Steel Tubing and Pipe. Which have possible applications in your products?

STAINLESS STEEL

Pressure Tubing

- ☐ Condenser Tubes
- ☐ Pipe—Schedule 40S
- ☐ Sanitary Tubes
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- ☐ Evaporator Tubes
- ☐ Bright Annealed
- ☐ Pipe—Lightweight Schedule 10S—5S
- ☐ Heat Exchanger Tubes

Mechanical Tubing

- ☐ Aircraft Exhaust
- ☐ Special Shapes
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- ☐ Polished Tubing
- ☐ Ornamental Tubing
- ☐ Clad Tubing Carbon—Stainless

CARBON STEEL

Pressure Tubing

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- ☐ Heat Exchanger Tubes
- ☐ Hydraulic Fluid Line
- ☐ Grooved End Tubes
- ☐ Refrigerator Tubes
- ☐ Water Wall Tubes
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- ☐ Condenser Tubes
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- ☐ Special Smooth I. D. Hydraulic Cylinder Tubes
- ☐ Hot Rolled Tubes
- ☐ Cold Rolled Tubes
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Cut out and send this check list for descriptive literature on Republic Tubing and Pipe applicable to your products.

REPUBLIC STEEL CORPORATION
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1441 REPUBLIC BUILDING • CLEVELAND 1, OHIO

Please also send me information on:

- ☐ Republic Cold Drawn Leaded Alloy Steels
- ☐ Republic Formed Part "Specials"
- ☐ Republic Century Series

Name__________ Title__________

Company__________

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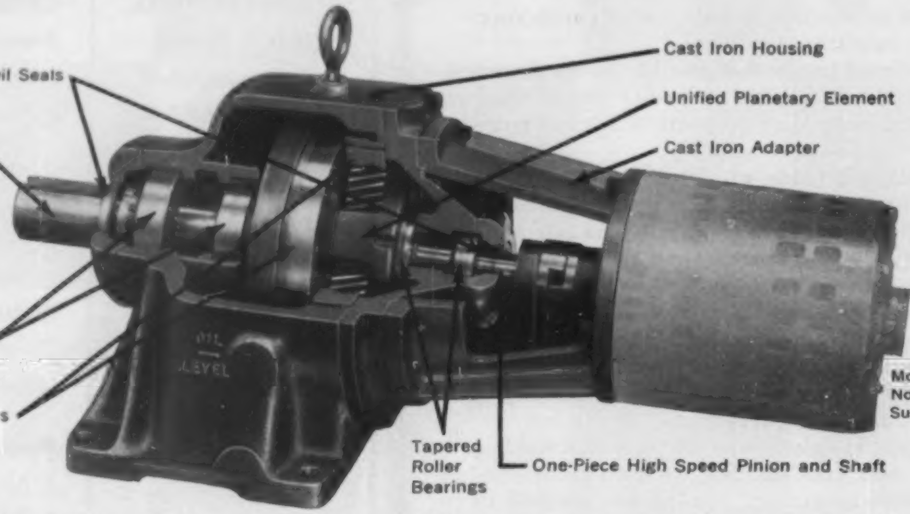
Engineering Data

WINSMITH SPEED REDUCERS

HORIZONTAL MOTORIZED DIFFERENTIAL SPEED REDUCERS



CAST IRON HOUSING—designed for high heat radiation. One-piece construction, close-grained gray iron for maximum strength and rigidity.

UNIFIED PLANETARY ELEMENT—integral primary and secondary planetary gears, mounted in a ductile iron cage—for even wear, equalized load, smooth operation. Hardened and ground, alloy steel gears carry entire power transmission load.

CAST IRON ADAPTER—permits use of any standard "C" flange motor. Flexible coupling (optional) connects motor to input shaft which can be driven in either direction.

INTERNAL RING GEARS—primary and secondary. Cut from alloy steel, heat treated for wear resistance.

ONE-PIECE HIGH SPEED PINION AND SHAFT—machined from alloy steel with teeth cut integral with the shaft. Hardened and accurately ground to close limits.

SLOW SPEED SHAFT—heat treated, precisely ground alloy steel. Low speed gear web of ductile iron.

TAPERED ROLLER BEARINGS—opposed pairs support the radial load, take thrust, ensure permanent alignment of both input and output shafts.

POSITIVE OIL SEALS—chevron type, keep oil in, dirt out. Oil and heat resistant, non-abrasive, low coefficient of friction.

AVAILABLE in any ratio from 1.1:1 to 50,000:1 without increasing the number of parts. Each model has a range of reduction ratios. Overall dimensions of individual models do not change regardless of ratio.

- *7 Models*
- *.12 to 81.51 H.P.*
- *Ratios 1.1:1 to 50,000:1*
- *Max. Output Torque 50 to 113,000 in. lbs.*

Series HM Horizontal Motorized Speed Reducers are a part of the Winsmith Planetary Differential Reducer line. They feature cut-tooth helical gears of 15° helix angle for smooth, positive power transmission—greater load carrying capacity—larger reduction ratios in smaller, more compact units—minimum wear and long service life. Winsmith Horizontal Motorized Differential Reducers are easy and convenient to install, require no bedplate, deliver more horsepower per pound of weight and cubic foot of space, and permit easier integration with the driven machine.

Write today for complete information or call your nearest Winsmith Representative listed in the Yellow Pages. He is a technically trained expert who is always ready to help you with any speed reducer problem. For both standard and special power transmission applications, you'll find it pays to standardize on Winsmith.

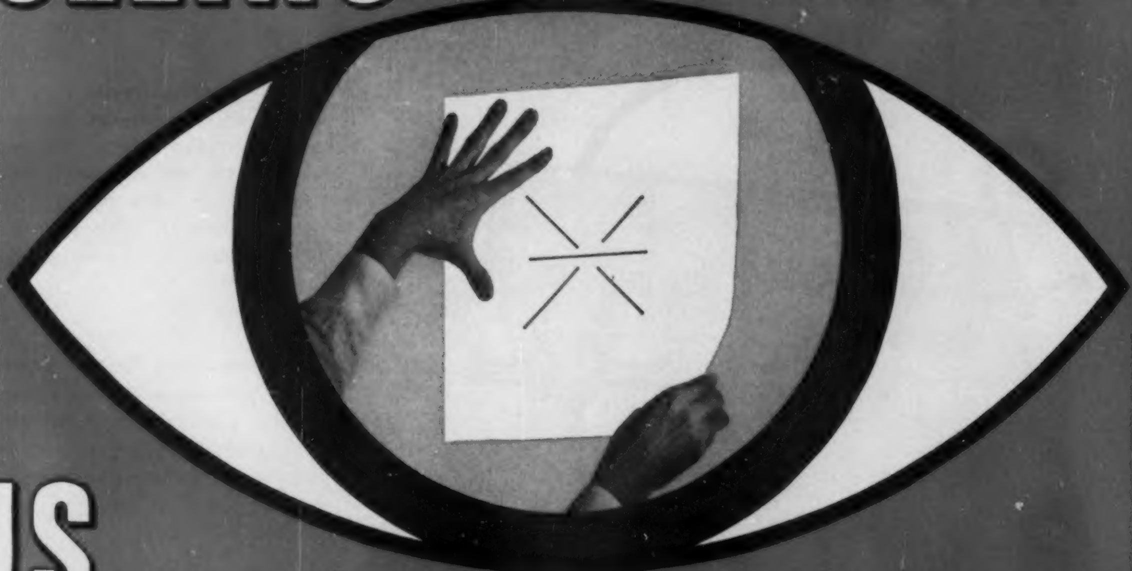
WINSMITH, INC.
202 Eaton Street, Springville, (Erie County), New York

MEMBER OF AGMA

• • • Winsmith Speed Reducers are made by American craftsmen to meet American design and production standards.

Circle 249 on Page 19

SEEING



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5

HITACHI

NO. 2 ML MILLING MACHINES

No. 2 ML Plain Milling Machine

Vibration Damping Device
Due to a vibration damping device of Hitachi's exclusive design contained within the over-arm, minimum vibration will be set up even during higher speeds and feeds operation, so that an excellent finished surface is obtained.

New-Type Arbor Support Bearing
Hitachi's unique super precision-type bearing, a combination of plain metal and needle bearing, is incorporated into the machine to enable high speed cutting with high precision results.

Mono-Lever Control System
Hitachi's unique Mono-lever Control System makes the operation simple and easy. Table-feeding too can be performed with ease.

Backlash Eliminator of Lead Screw
As the use of two independent nuts eliminates backlash on the table feed screw, smooth down-cutting can be effected.

SPECIFICATIONS:

- 53 1/8"×10 1/16" Table
- 28" Longitudinal Traverse
- 16 Table Feeds 1/16"—78 3/4"/min.
- 16 Spindle Speeds 25—1,500 r.p.m.
- 7.5 h.p. Main Motor

Hitachi, Ltd.
Tokyo Japan

Cable Address: "HITACHY" TOKYO

Shown here are just a few of the many different types in the Bulletin 802T line.

These Allen-Bradley Oiltight Limit Switches Are Hard To Beat!

You'll find exactly what you need in the wide variety of Allen-Bradley Bulletin 802T oiltight limit switches. Also, you can be certain that your selection will provide many millions of reliable operations, no matter how severe the service may be. Allen-Bradley proves these facts to itself—for the benefit of its customers —by continuously conducting accelerated life tests far more grueling than ever encountered in service.

All of these rugged Bulletin 802T oiltight limit switches have operating heads and switch bodies that are completely sealed. It is impossible for oil or dirt to enter and cause contact fouling or sluggish operation. The precision switch mechanism maintains high contact pressure up to the instant of snap-over. Vibration cannot cause contact chatter and arcing. As with all A-B control, the double break, silver contacts never need servicing.

Specify Allen-Bradley Bulletin 802T oiltight limit switches and obtain "extra" millions of trouble free operations and longer life. As you know, "downtime" is enormously expensive. The difference in price between an A-B limit switch and some other make is not worth the gamble! For full details, please write: Allen-Bradley Co., 1333 South First Street, Milwaukee 4, Wisconsin. In Canada: Allen-Bradley Canada Ltd., Galt, Ontario.

ALLEN-BRADLEY

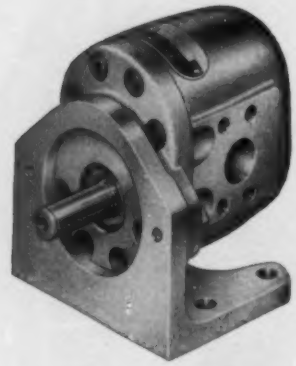
Member of NEMA

QUALITY MOTOR CONTROL

Circle 252 on Page 19

For peak

- **EFFICIENCY**
- **PERFORMANCE**
- **RELIABILITY**
- **ECONOMY**



BERRY/DOWTY*
Hydraulic Gear Pumps

pressures to 3000 psi
speeds to 6000 rpm
outputs to 85 gpm

Berry/Dowty hydraulic gear pumps provide superior performance over a wider range of operating speeds, pressures, temperatures and fluid viscosities than can be obtained with ordinary gear pumps.

How? With advanced design and construction . . . volumetric efficiencies well above 90% . . . an advanced method of wear-compensating pressure loading . . . massive journal-type bearings . . . positive metered lubrication even at 0 psi output . . . low noise level . . . all these in a compact, rugged aluminum housing for minimum weight.

Whether you build or use hydraulic powered equipment, you'll find that Berry/Dowty gear pumps offer far more in performance, reliability and low cost of ownership. Your Bellows-Valvair Field Engineer has proof.

*Manufactured by Berry Hydraulics under license from Dowty Corp. for Bellows-Valvair Hydraulics Division, Salem, Ohio.

3065

For more information, write for Bulletin HP-311. Address Bellows-Valvair, Hydraulics Division, Salem, Ohio, Dept. MD-1261.

Bellows-Valvair
Division of IBEC SALEM 9, OHIO

These names assure you the best in pneumatic, hydraulic and electronic components
BELLOWS · VALVAIR · SINCLAIR-COLLINS · HUNT · HYQUIP · JACKSON ELECTRONICS

Circle 253 on Page 19

Circle 254 on Page 19→

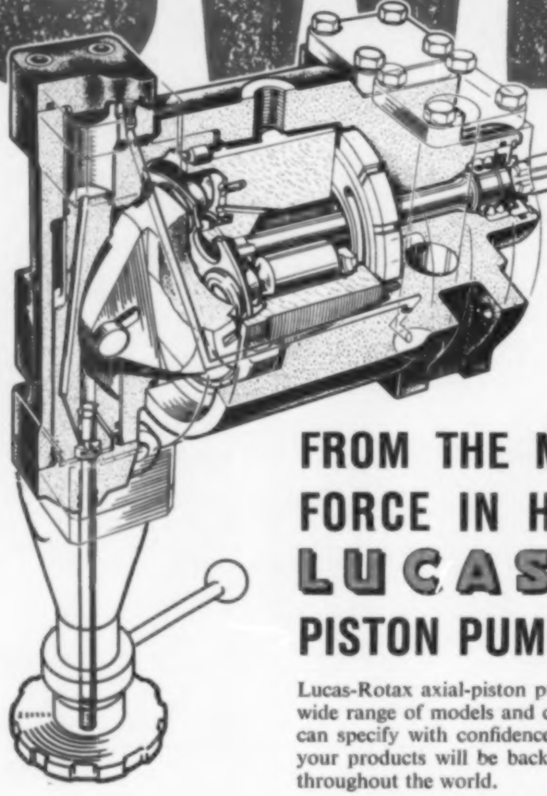
N-S Wire Cloth . . .

The versatile metal cloth for screening, filtering, radio frequency shielding, fabricating, ventilating . . . for thousands of modern industrial uses. Reynolds Wire Cloth is woven on special-built looms, in square weaves up to 250 mesh, filter weaves up to 2500 mesh. N-S produces all types of wire cloth including new high temperature superalloys. Consult N-S today for your special requirements.

NATIONAL-STANDARD COMPANY
Reynolds Division
Dixon, Illinois

A NEW POTENTIAL IN FLUID

POWER



FROM THE MOST ADVANCED FORCE IN HYDRAULICS . . .
LUCAS-ROTAX
PISTON PUMPS AND MOTORS

Lucas-Rotax axial-piston pumps and motors are available in a wide range of models and capacities to match your needs. You can specify with confidence—the domestic and export sales of your products will be backed by Lucas-Rotax service facilities throughout the world.

Lucas-Rotax high pressure pumps range from 4 to 104 g.p.m. at pressures up to 5,000 p.s.i.. *Lucas-Rotax hydraulic motors* are available in the same flow and pressure ranges.

Both pumps and motors can be supplied in fixed or variable volume versions. The variable volume control is power assisted to allow displacement adjustment while operating under load. Pressure compensation and other types of controls are available.

Our sales engineers are fully qualified to discuss your design ideas in all areas of fluid power application. Write now for full information from the most advanced force in hydraulics!

LUCAS-ROTAX LIMITED

2200 EGLINTON AVE. EAST, TORONTO, ONTARIO.
POSTAL ADDRESS: BOX 115, STATION H, TORONTO 13.

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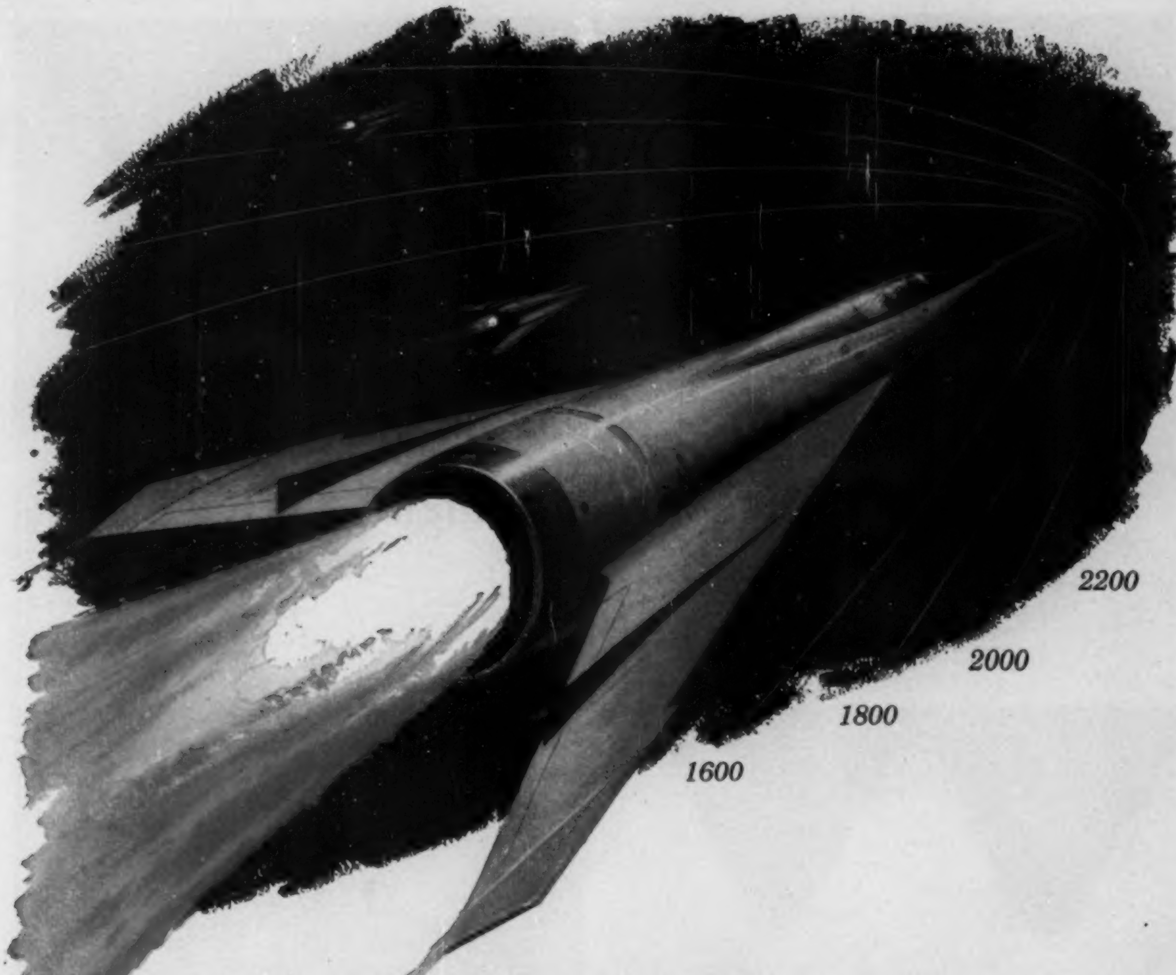
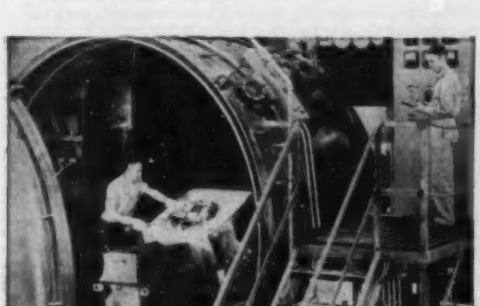


Tempering temperature's temper



Complete vacuum melting equipment is part of HAYNES STELLITE's modern plant facilities. For full details, write for 48-page descriptive booklet.

Heat of 2000+ deg. F. is generated in a supersonic jet's tailpipe. So is extreme vibration.

By far the best alloy tested for this critical component is MULTIMET alloy—one of 12 HAYNES alloys helping combat heat, stress, and erosion in the jet engine, missile, and rocket field.

HAYNES alloys are relied on for use in afterburners, turbine blades, nozzle vanes, and many other high-temperature parts. All 12 HAYNES high-temperature alloys are *production* alloys and are readily available. Some are vacuum melted. Some air melted. Some are cast, some wrought, some are produced in both forms.

HAYNES
ALLOYS

HAYNES STELLITE COMPANY
Division of Union Carbide Corporation
Kokomo, Indiana

UNION CARBIDE

Address inquiries to Haynes Stellite Company, 270 Park Avenue, New York 17, N. Y.

"Haynes," "Multimet," and "Union Carbide" are registered trade-marks of Union Carbide Corporation.

PQA* proves it

This Allen screw passes multi-million-cycle test under high load conditions

50X Magnification—unretouched

Here you see a competitive socket-head cap screw where thread laps and deep decarburization (lighter area running through roots of threads) caused premature failure of the screw. When used under high load conditions in an outboard crankshaft-connecting rod-piston assembly, such a screw failure would cause great motor damage.

50X Magnification—unretouched

Now look at this Allen Socket Cap Screw. Photo was taken during regular quality control test and shows no thread lap or decarburization. Allen is producing to and inspecting in accordance with MIL-B-7838A for thread discontinuities—your assurance of quality!

*PRODUCT QUALITY ASSURANCE

PQA is the symbol of unquestioned quality at Allen. It stands for *constant* quality control from rigid upgrading of incoming raw materials to shipment of finished products—*plus* an unconditional guarantee that backs up every order!

Quality checks like the one illustrated confirm PQA every step of the way through Allen's manufacturing process. Remember . . . it costs no more to have *genuine* Allens right from stock, and they are only a minor fraction of your assembly costs.

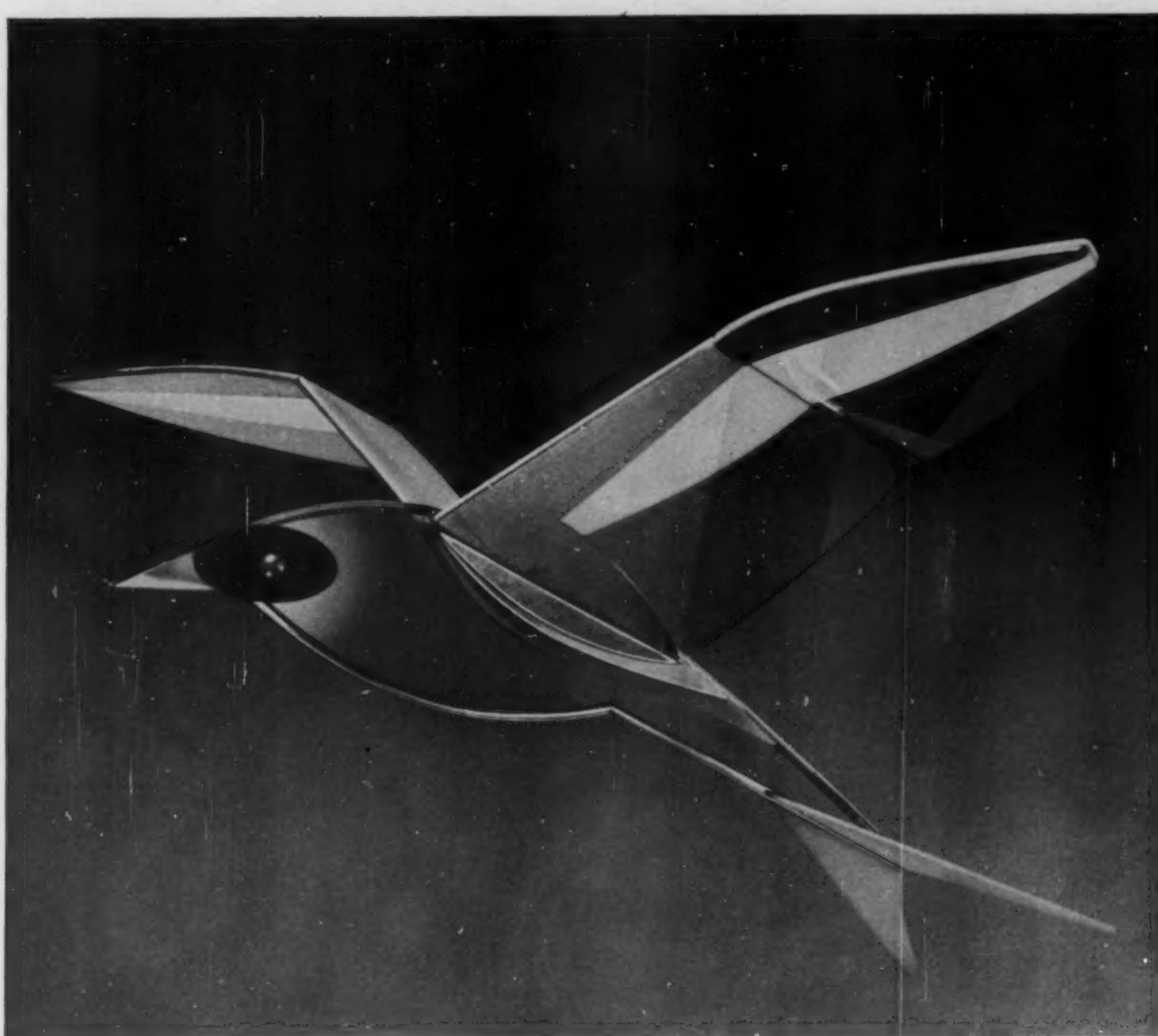
Genuine ALLEN products are available only through your ALLEN Distributor. He maintains complete stocks close by to help cut your freight costs, inventory, warehousing and handling. He offers fast, single-source service. He knows ALLEN products. And he makes ALLEN Engineering Service available to you any time. Call him!

ALLEN

MANUFACTURING COMPANY
HARTFORD 1, CONNECTICUT, U.S.A.

ALLEN HEX-SOCKET SCREWS HEAD

Plant at Bloomfield, Connecticut • Warehouses in Chicago, Cleveland and Los Angeles



Sculpture created especially for 3M Company by Guy Palazzola

FEATHER-LIGHT...

3M Adhesives help take pounds off today's metalworking products

Reducing dead weight can give a product extra sales advantages . . . make it easier to handle and assemble . . . lower shipping and production costs. The answer: Fabricate with 3M Industrial Adhesives and save weight without sacrificing strength.

In fact, 3M Adhesives often substantially increase the strength of an assembly by distributing stresses evenly over a wide area, making lightweight, high-strength designs possible. And without mechanical fasteners that lower the integrity of the material and cause stress points that tear, fabricators can substitute lighter gauge materials.

For example, 3M Adhesive EC-1357—only one of a complete line of strong, general purpose industrial adhesives—finds wide application in products requiring strength and light weight. It is used in the bonding of metal frames to veneered plywood . . . in honeycomb construction for table tops . . . in sandwich-type wall panels, where it bonds porcelain enameled steel to an expanded glass core.

Backed by a quarter century of research, 3M Technical Service is solving fabrication problems for leading manufacturers in various industries. For an accurate appraisal of how an adhesive can add strength, light weight, production economy, and greater design freedom to your process or product, look first to 3M. Write AC&S Division, 3M Company, Department SBR-121, St. Paul 6, Minnesota.

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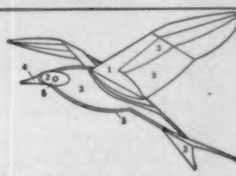

What do you want to bond to what?

The Bird is fabricated of these materials and bonded with a variety of 3M Adhesives:

1. Stainless Steel 2. Wood 3. Plastic 4. Glass 5. Brass.

ADHESIVES, COATINGS AND SEALERS DIVISION

MINNESOTA MINING AND MANUFACTURING COMPANY

. . . WHERE RESEARCH IS THE KEY TO TOMORROW

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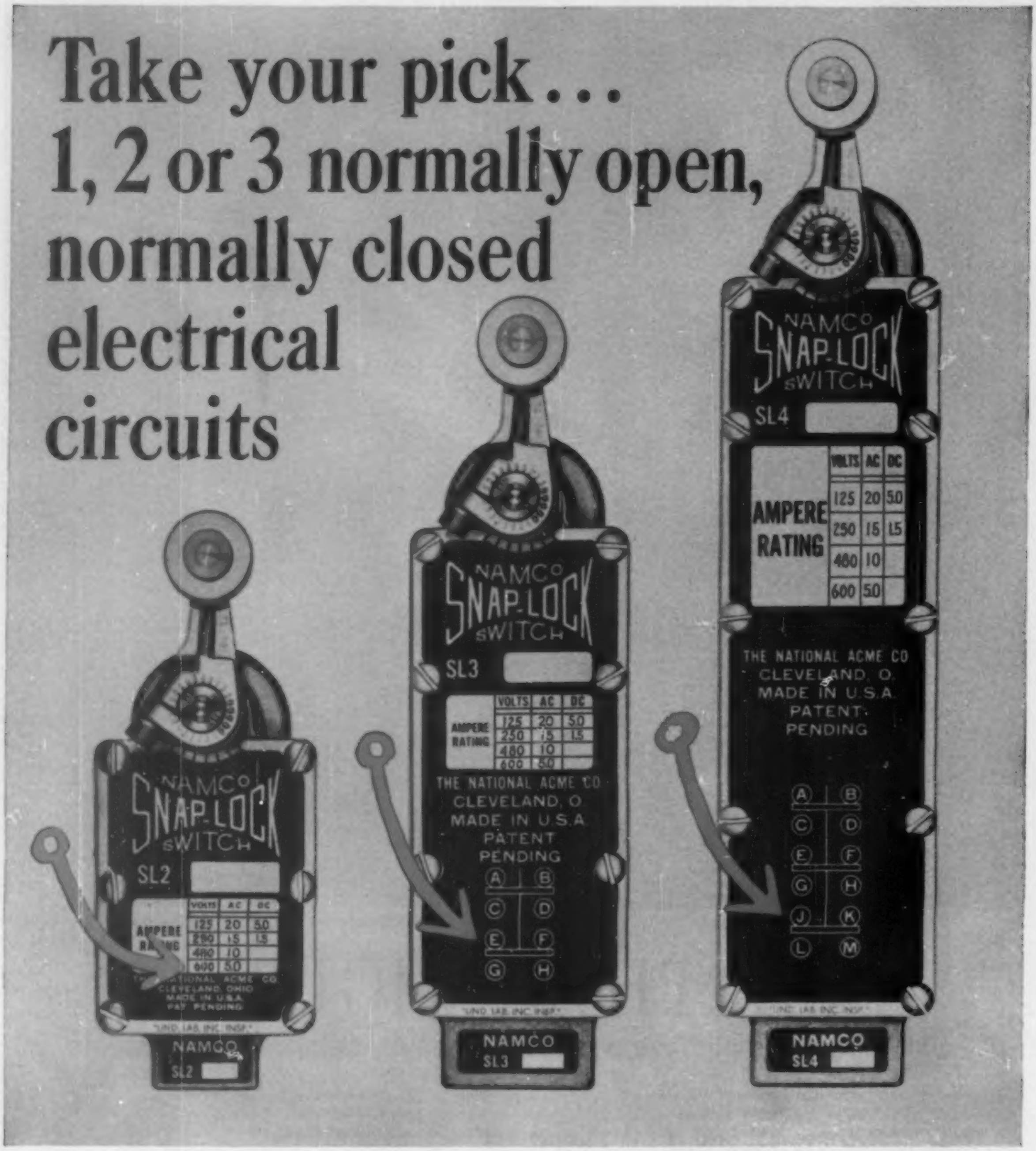


What does your limit switching application call for . . . one, two or three normally open, normally closed electrical circuits? Whatever it is, one of these National Acme SL "Machine Life" Limit Switches . . . the SL2, the SL3 or the SL4 . . . will meet your precise requirement. And, every SL offers . . . a variety of cam arrangements for extreme operating flexibility . . . ample overtravel (67°) and by-pass (90°) . . . light operating pressure (10½ lbs. at 1½" radius). Also available . . . the SLS 2, 3 or 4 featuring "hi-shock" sliding contacts: particularly suitable for drop forge, punch press and other heavy equipment application. Call, write or wire for complete information.

National Acme

THE NATIONAL ACME COMPANY
188 E. 131st STREET
CLEVELAND 8, OHIO

Sales Offices: Newark 2, N. J., Chicago 6, Ill., Detroit 27, Mich.

Circle 259 on Page 19

Got a severe WEAR problem? Your answers are in this booklet

This new booklet is crammed with information on Carmet Cemented Carbides . . . man's hardest, most abrasion resistant metal . . . and on design techniques that make the most of Carmet's unique properties.

Properly designed, Carmet Cemented Carbides give outstanding service in applications involving severe wear and abuse. They possess an extraordinary combination of extreme hardness and strength, higher than any metal or alloy . . . cast, rolled or forged. They have three times the stiffness of steel . . . up to 100 times the abrasion resistance.

In Carmet's new booklet, the designer will find the charts, graphs, case histories, and tables of information needed for intelligent selection and application of the Carmet Cemented Carbides. And, there's a special section on design criteria for top performance. Ask your local Allegheny Ludlum representative for a copy, or write: ***Allegheny Ludlum, Carmet Division, Oliver Building, Pittsburgh 22, Pennsylvania. Address Dept. MD-12.***

CARMET® AL

CEMENTED CARBIDE • DIVISION OF ALLEGHENY LUDLUM

2008

Circle 260 on Page 19

PLATINUM POINTS THE WAY TO LOWER COSTS

The low cost of platinum is real, because of its long life, high recovery rate and scrap value (once you have purchased platinum, you have it almost forever).

LONG LIFE—it is almost indestructible, even in the most difficult environment.

EXCELLENT RECOVERY—most of the original metal is easily recovered, even after years of use.

HIGH SCRAP VALUE—the dollar value of recovered scrap is almost as great as the original metal cost.

When you need Platinum, take advantage of BISHOP's long experience (. . . since 1842), ample supply . . . broad capabilities:

- FORMS—foil, gauze, plate, sheet, strip, tubing
- WIRE—pure, commercial, composite, thermocouple
- LABORATORY APPARATUS
- CLADS AND BIMETALLICS
- CHEMICALS
- CATALYST RECOVERY
- SCRAP CONVERSION

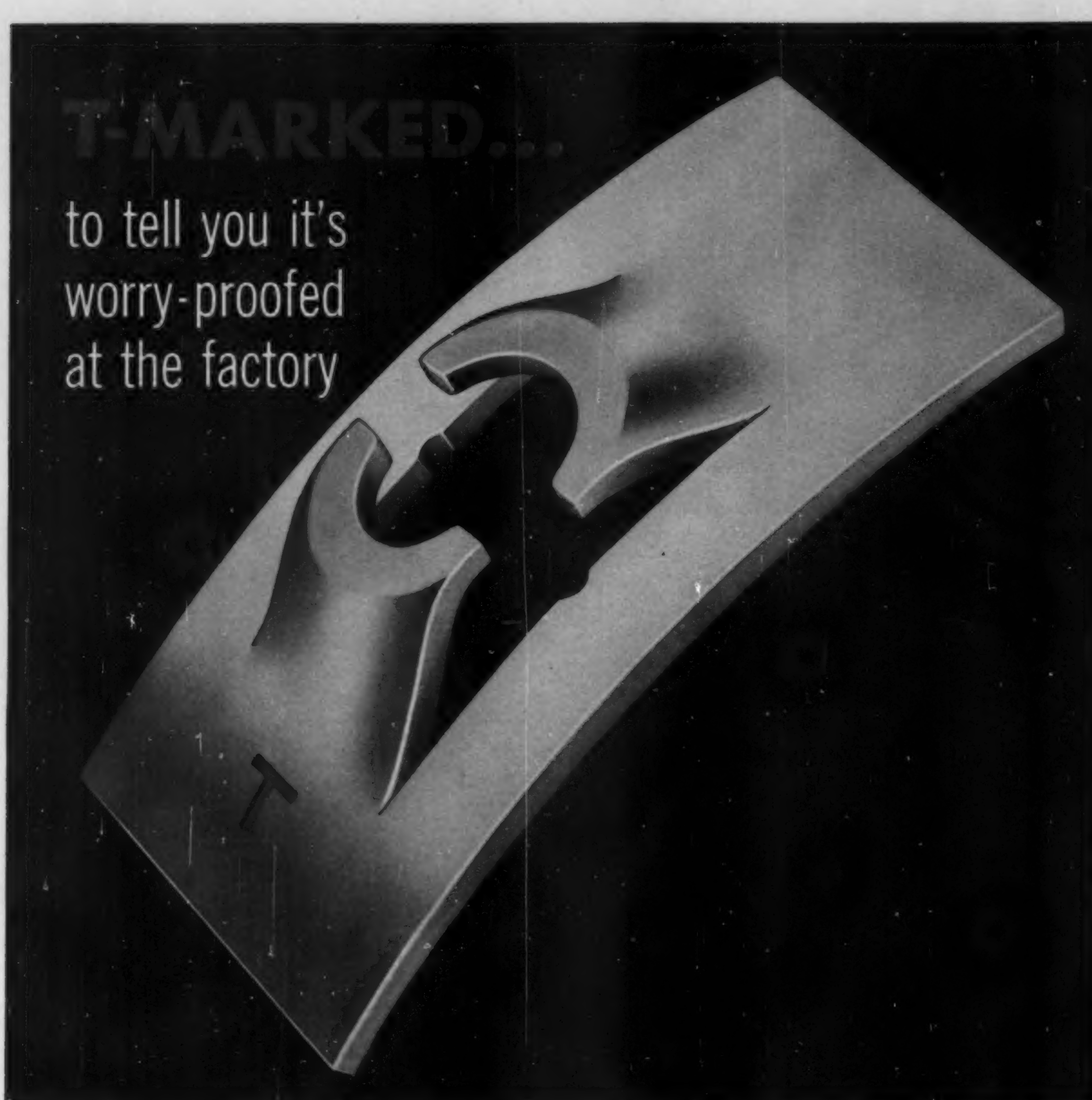
For the full story, write for Bulletin P-6.

BISHOP

J. BISHOP & CO. *platinum works* / MALVERN, PENNSYLVANIA

A JOHNSON MATTHEY ASSOCIATE "METALS FOR PRECISION AND PERFORMANCE"

OFFICES: NEW YORK • PITTSBURGH • CHICAGO • ATLANTA • HOUSTON • LOS ANGELES



Other spring fasteners may look like Tinnerman SPEED NUTS. But only the *T-marked* ones really are SPEED NUTS . . . really are "Tinnermans". . . made to highest quality and precision standards to assure worry-proof performance on your assembly.

Here's what the exclusive Tinnerman T-mark means to fastener users:

Over thirty-five years of Tinnerman experience as the originator and largest producer of spring-steel fasteners...the leader in solving your fastening problems,

Outstanding fastener design and production experience that assures you the best possible design of SPEED NUT, whether it is a special SPEED NUT or one of the 10,000 SPEED NUT brand fasteners presently available,

Stringent control of SPEED NUT quality from coil strip to you, including die design, production, heat treatment and finishing.

Be sure you specify "Tinnerman T-marked SPEED NUTS" that give you better fastening, that cut parts and assembly costs, that never let you or your customer down. *Tinnerman Products, Inc., Dept. 12, Box 6688, Cleveland 1, Ohio.*

CANADA: Dominion Fasteners Ltd., Hamilton, Ontario.
GREAT BRITAIN: Simmonds Aerocessories Ltd., Treforest, Wales.
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TINNERMAN
Speed Nuts®
Look for the Tinnerman "T"

Which of these parts should be investment cast?

. . . *All* the parts except the milling machine collet at the top right—which is a "natural" for conventional lathe work. Even the helical impeller the men are examining is best made as an investment casting—the helix is undercut in such a way that no cutting tool could reach inside to remove the metal.

"Naturals" for investment casting are usually parts that are too intricate to be made economically by any other process, or involve alloys or quantities that make them impractical to produce by other methods. In other words, when it looks as if you might have to sacrifice a design because its complexity makes the cost prohibitive, or forego a preferred alloy because it is difficult to machine, then it's time to take a long, hard look at investment casting.

But . . . it's not always as easy as it sounds to spot the parts that are "made" for investment casting. That's where the Arwood sales engineer comes in. He knows Arwood expects him to show a customer how to get the most from the process. To help keep your cost down he may have to suggest a filleted radius here . . . or a tolerance opened up there. Then too, on occasion he may readily have to admit the part should not be investment cast at all. However, he also knows that if you just can't have the part made any other way, Arwood will go all the way down the line to have it investment cast for you.

Our five plants cast every castable metal and alloy, including magnesium and superalloys. Each has its own research, tooling, quality control and production facilities. In short, if it can be investment cast, we can investment cast it.

LIKE TO LEARN MORE ABOUT INVESTMENT CASTING?

Write us for a complimentary copy of our 44-page manual, "Practical Guide to Investment Casting." Among other sections it includes practical tips on designing for investment casting, as well as analyses and physical and mechanical properties of all the metals and alloys cast by Arwood.

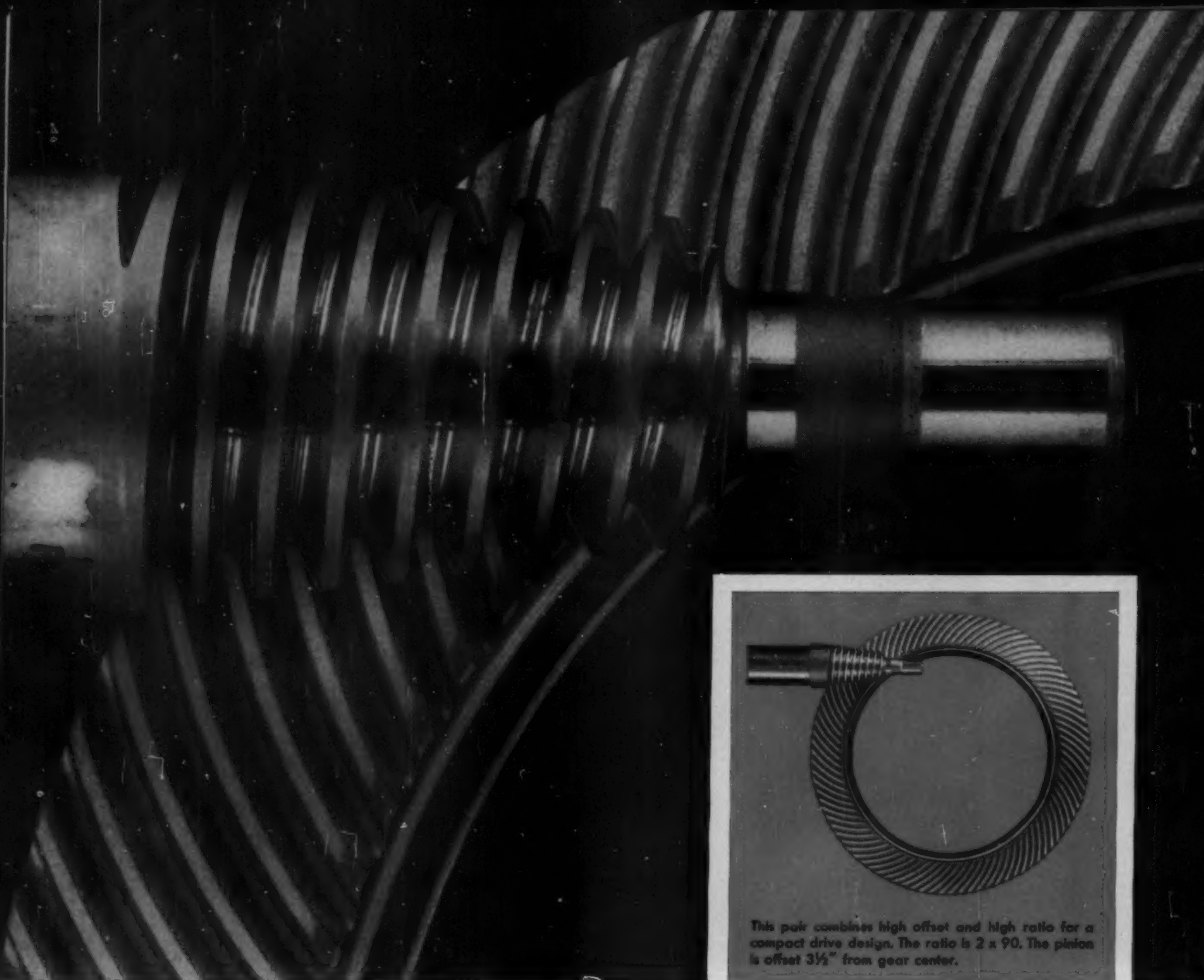
Machine the simple . . . cast the complex

A complete service from design through tooling, production and finish machining. Seventy-one engineering representatives from coast to coast.

arwood

ARWOOD CORPORATION • 315 West 44th Street, New York 36, New York

PLANTS IN BROOKLYN, N. Y.; TILTON, N. H.; GROTON, CONN.; LOS ANGELES AND LA VERNE, CALIF.



This pair combines high offset and high ratio for a compact drive design. The ratio is 2 x 90. The pinion is offset 3½" from gear center.

See how the teeth "wrap around" this high-reduction pinion

This is a high-ratio hypoid gear. In principle, it is not different from more conventional hypoids produced by the Gleason Works. *But . . .*

If you look closely at the pinion, you'll notice that the teeth tend to "wrap around" it. This design is extremely well suited for high reduction, strength and compact design.

The result is a conical (or sometimes cylindrical) pinion which permits *continuous tooth action—even with just one or two teeth!* Compared to corresponding bevel pinions, its diameter is greater for higher strength. An extended shank on cylindrical pinions makes *very rigid* straddle mountings practical.

You can design a *compact* unit, because high offset is possible! For high-offset *or* high-ratio pairs, the "wrap around" tooth design provides an extra measure of the smooth, quiet tooth action of hypoid gears.

High-ratio hypoids can be cut on the same Gleason equipment that is used on more familiar spiral bevel gears and hypoids. You can also use the same testers, quenching presses and other auxiliary Gleason equipment you're using now. Grinders are available for applications requiring precision finish.

High-ratio hypoids can be produced by the Gleason Works for ratios of 1:10 or 1:40 or even higher. They are finding a growing number of applications in such diverse fields as farm machinery, instrumentation and office equipment.

You can get more information about Gleason high-ratio hypoid gears by writing for free literature. Submit your prints for recommendations.

GLEASON WORKS

1000 UNIVERSITY AVE., ROCHESTER 3, N.Y.

Circle 264 on Page 19

Why do design engineers bring their defrosting, de-icing and heating problems to SAFEWAY?

The photo above provides a pretty good answer. **SAFEWAY** designs, engineers and manufactures just about every conceivable type of *controlled-heat* product you can think of. **APPLICATIONS?** From air conditioning units—to ground support equipment—to rockets—and scores of "in-betweens". **CONSTRUCTION?** Heating elements or blankets; woven or strung; laminated, molded and bonded to metals and plastics or both. Corrosion resistant, immersible. **SIZE?** Large, small, thick or thin. **INSULATIONS?** Silicone rubber, epoxy resin, neoprene, fiberglas, butyl, to name a few. **SERVICE?** All the way from *one source*—from engineering recommendations to the completed unit—produced on time in our modern manufacturing facilities. Write or call us on your problem. Our years of industrial and military experience are at your disposal.

Write today for our fact-filled brochure, describing the wide range of materials, specifications and application possibilities. Safeway engineers will gladly analyze your requirements and submit practical recommendations.

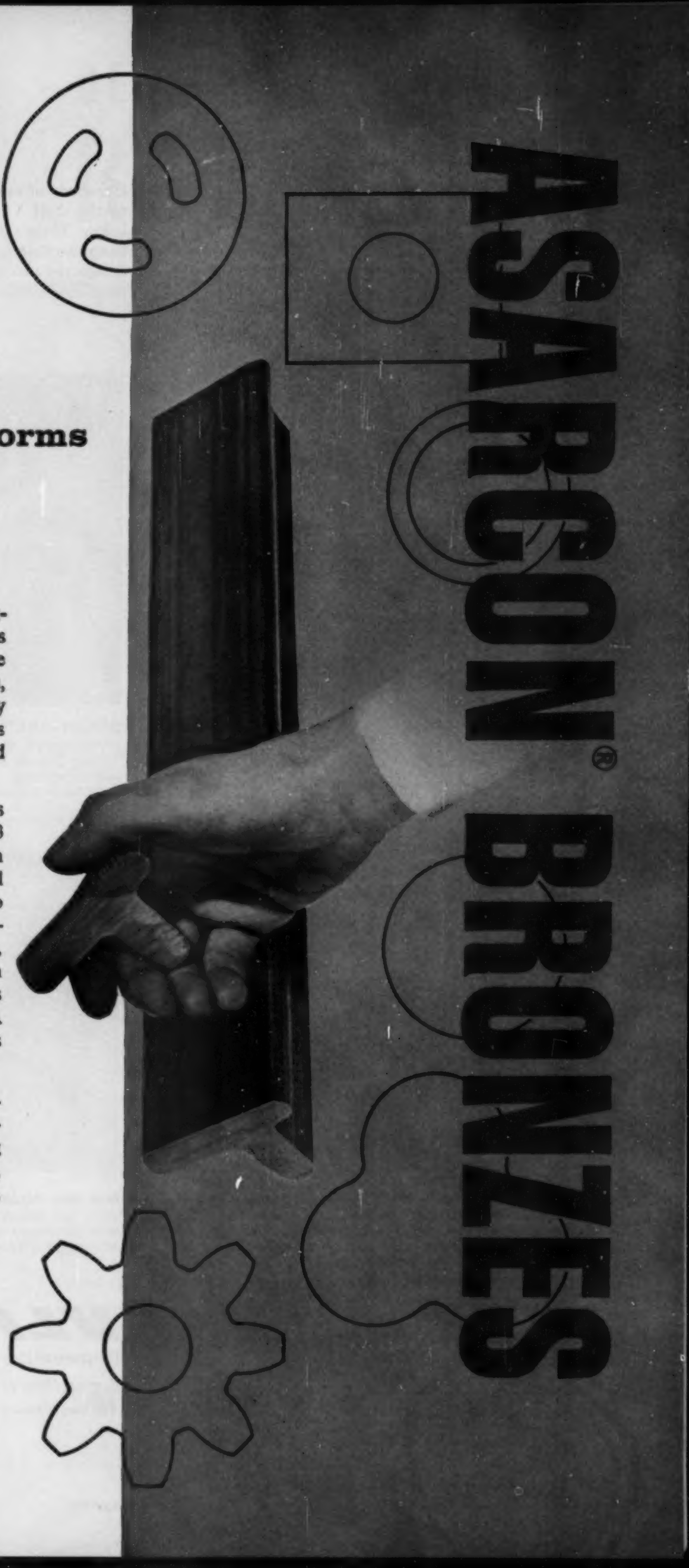
Safeway HEAT ELEMENTS INC.

Middlefield Street • Middletown, Connecticut

Circle 265 on Page 19

ASARCON

custom shapes and forms in any lengths you need



Asarcon continuous castings give you an extremely wide variety of shapes and forms in standard bronze alloys. They will increase your production rates and lower your costs, because: you get the shape you want in any length you need up to 20 feet. This permits machining on automatic screw machines and other high-speed equipment.

Continuous casting of Asarcon bronzes raises fatigue characteristics of standard alloys 33 to 100%, increases impact strength from 15% to more than double that of identical alloys cast other ways, adds materially to tensile, yield strengths and hardness. Asarcon 773 (SAE 660) bearing bronze in solids, rods and tubes is immediately available from stock in your choice of more than 260 sizes up to 9" O.D. and lengths up to 105". A wide variety of other special alloys, shapes and sizes produced to order.

For complete data on Asarcon continuous-cast bronze, write Continuous-Cast Department, American Smelting and Refining Company, Perth Amboy, N. J., Whiting, Ind.; or 120 Broadway, New York 5, N. Y.

ASARCO

Circle 266 on Page 19

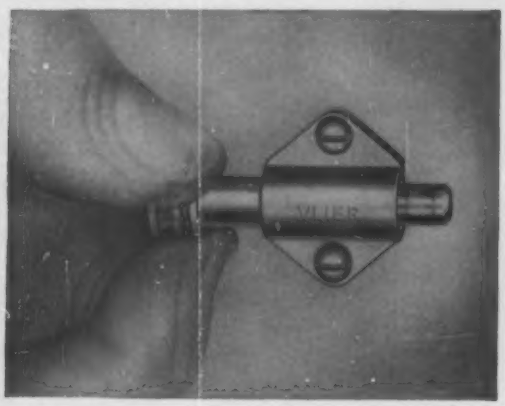
Practical Design Tips

No. 4 of a series

Hundreds of companies are now saving by using off-the-shelf Vlier products like the ones shown below. These simple, low cost, precision parts save designers time and, in many cases, simplify product design and manufacture. Why not investigate their possibilities today.

BALL PLUNGERS WORK BETTER than spring plungers when side loads are involved. Balls won't bind from side thrusts, retract easily. Available in 10 standard sizes from 4-48x3/16" to 5/8-11x1". Various end pressures. Special sizes and end pressures made to quantity orders.

TORQUE-LIMITING WRENCH for assembling small parts, adjusting set screws, etc., is easily made from a Vlier Torque Handle and a length of hexagon stock. Prevents over-tightening, and subsequent damage to parts. End pressure is adjustable from 15 to 200 lbs.



NEED A SMALL, LIGHTWEIGHT, SPRING-LOADED LATCH? One enterprising designer modified a standard Vlier S-88 Spring Stop that did the job perfectly. Entire latch weighs less than 1/3 oz. Body is die-cast aluminum; plunger is heat-treated alloy steel. Various plunger pressures. Available on quantity orders only.

FREE IDEA BOOKLET. Illustrations in this 16-page booklet show how others have profited from the use of Vlier products. Illustrates both the usual and unusual applications. May suggest ways *you* can save. Write for your copy today.

VLIER
Engineering Corporation
A subsidiary of Barry-Wright Corporation
8900 Santa Monica Blvd. • Los Angeles 69, California

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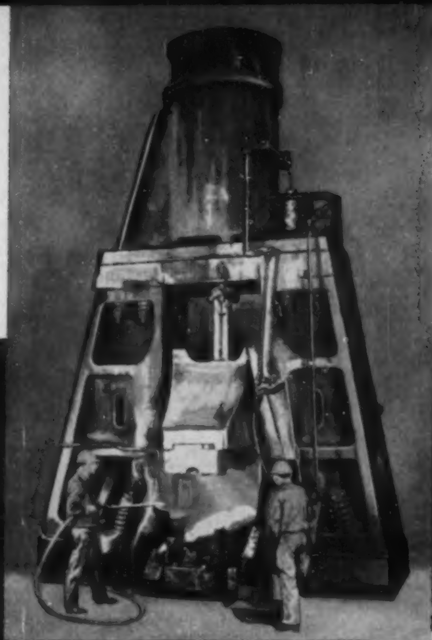
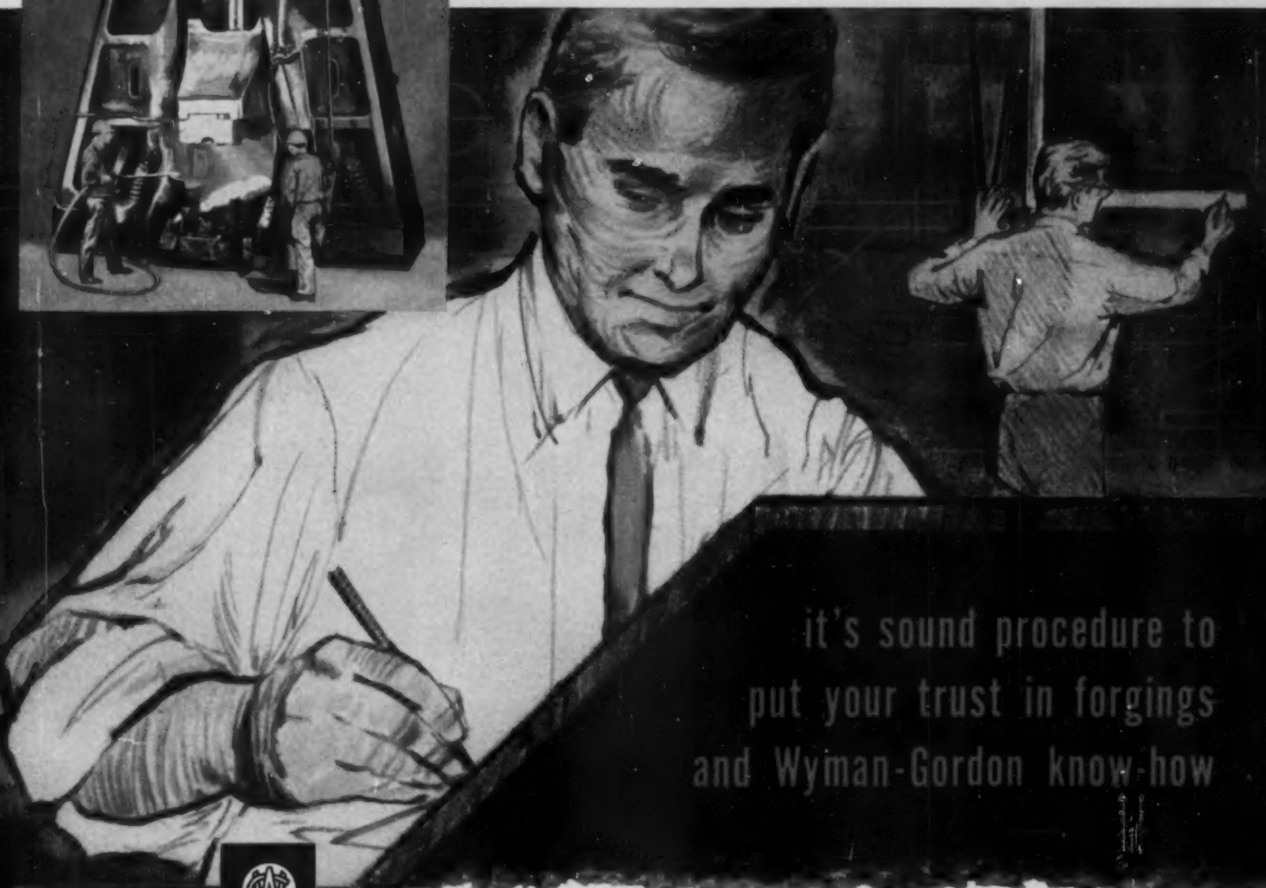
DESIGNING FOR GREATER RELIABILITY





Forgings simply have no "or equal" in meeting the tight specifications on reliability a designer must write today. Take your metallurgist's word for that. No other process he knows of can make such basic contributions to part integrity . . . develop physical properties to such optimum values . . . or control vital grain flow with like precision. For no other method approaches forging in the consistent soundness and superior metal quality needed for unfailing performance. As a forging supplier, Wyman-Gordon is equally outstanding . . . offering unduplicated hot-working experience, materials knowledge and facilities which substantially extend design latitude in solving product reliability problems.

WYMAN-GORDON

FORGINGS

of Aluminum Magnesium Steel Titanium . . . and Beryllium Molybdenum Columbium and other uncommon materials

HARVEY ILLINOIS WORCESTER MASSACHUSETTS GRAFTON MASSACHUSETTS
DETROIT MICHIGAN LOS ANGELES CALIFORNIA PALO ALTO CALIFORNIA FORT WORTH TEXAS

Circle 268 on Page 19

WG4

Stainless steel filters are induction brazed at Dynamic Filters, Inc., Detroit, Mich., using EASY-FLO brazing alloy and Handy Flux for 100% joint integrity.

SILVER BRAZING—the precise tool for precision fabricating

The ability of silver brazing to serve fabricators literally through thick and thin is well illustrated by the experience of Dynamic Filters, Inc.

This firm manufactures fine filters for industrial, aircraft, missile, nuclear and marine use by bonding woven wire cloth of desired mesh to a coarser backing screen, forming and joining to required shape and attaching necessary fittings.

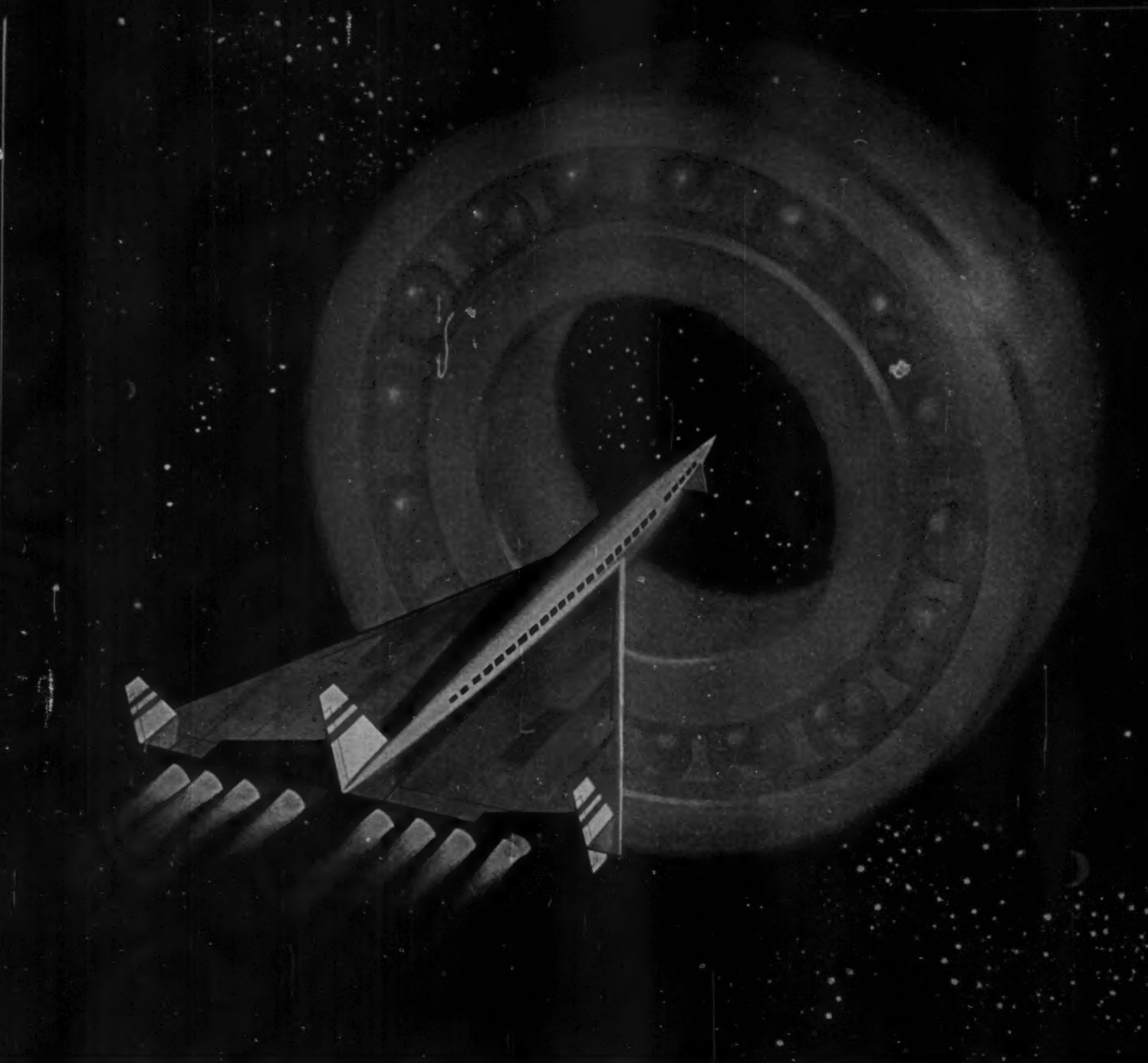
Since the filters must be capable of screening out particles ranging down to 2 microns in size, often under heavy pressure, any flaws in joint material or method would naturally be fatal. Dynamic Filters gets complete joint reliability by silver brazing with Handy & Harman EASY-FLO brazing alloys and Handy Flux. How do they know? They inspect all joints 100%.

Equally decisive in their choice of silver brazing is its compatibility with both the relatively thick fittings and thin wire mesh. EASY-FLO melts quickly at relatively low temperatures so metal is not annealed, oxidized or otherwise damaged, forms a thin, molten metal film that penetrates into small voids and capillary spaces, then solidifies to form strong, neat joints requiring little or no finishing.

Add to this the advantages of volume production at often negligible expenditure in brazing materials and you'll see why silver brazing is becoming more and more the favored method for beating fabrication costs. Get complete information—send for a copy of our data-packed Bulletin 20. It's yours for the asking. Write today.

HANDY & HARMAN
850 Third Avenue, New York 22, N.Y.

Circle 269 on Page 19



BEARING WITH A RED HOT FUTURE

SKF MOTION ENGINEERING

Advanced ball and roller bearing technology

On special test equipment in SKF's research laboratory, experimental ball and roller bearings are run at temperatures up to 1000° F and above—conditions under which steel becomes red hot and loses its strength, while conventional lubricants burn or boil away. To meet these problems, bearings made of special heat-resisting alloys and exotic new materials are tested and evaluated. New ideas in design and new approaches to lubrication are constantly being investigated.

Bearings to resist extremely high temperatures are needed for improved, high performance jet engines, gas turbines and other equipment. Special SKF bearings have been tested successfully in environments at about 1000° F. Under certain conditions of operation, much higher temperatures are practical.

Research like this is your assurance that SKF will always keep pace with demands for the highest possible performance in all major types of rolling contact bearings—ball, cylindrical roller, spherical roller, tapered roller and precision miniature. SKF Industries Inc., Philadelphia 32, Pa.

6103

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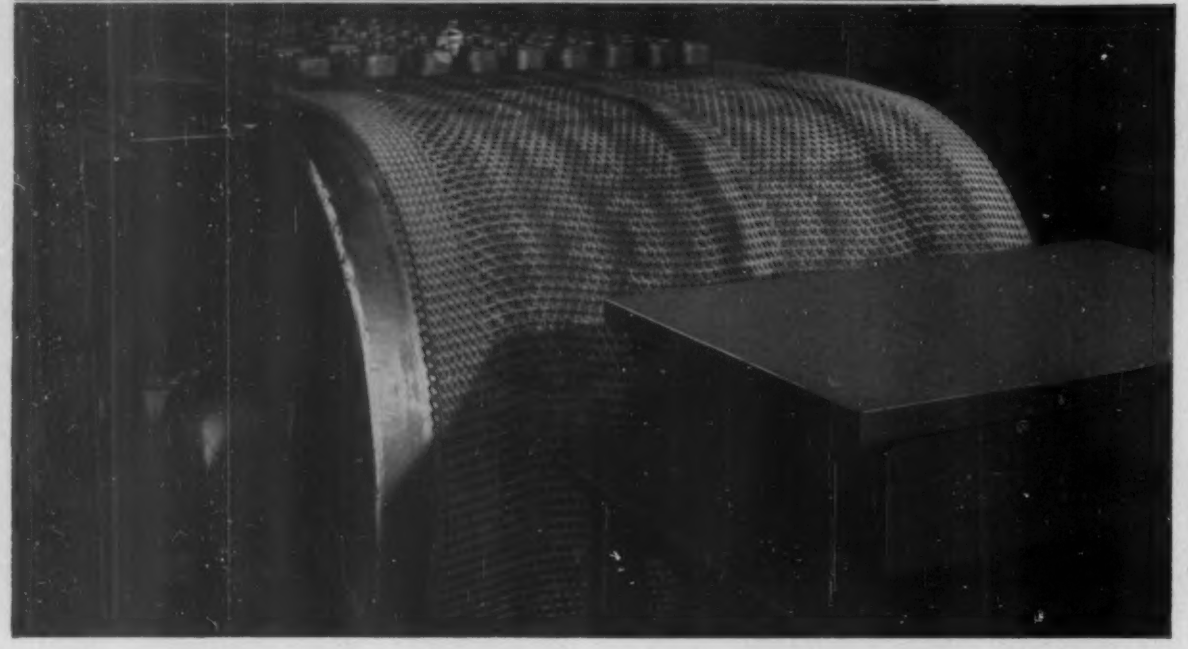
Cambridge Type-314 Stainless Metal-Mesh Belt



SOLVES CHANGING TEMPERATURE, CHANGING LOAD PROBLEMS

Looking for a low-cost, all-purpose belt? Then look closely at a Cambridge Type-314 Stainless Steel Metal-Mesh Belt. It has the outstanding ability to give long life under widely varying load conditions in both high and medium temperatures. You can use it in 2100° F. to 1850° F. temperatures and get excellent strength characteristics and oxidation resistance. In the 1850° F. to 1600° F. range, it shows superior resistance to green rot. In the 1600° F. to 900° F. range, it shows little or no carbide precipitation.

To meet specific requirements, there is a complete line of Cambridge Belts available in special and standard metals and alloys—custom built in any weave to insure the most efficient processing.

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Circle 271 on Page 19

Circle 272 on Page 19→

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The complete line—engineered for reliability—precision drawn stainless steel wire, music spring wire, flat wire and strip, superalloy wire, heavy galvanized wire, plated wire, rocket wire (extra high tensile). Other wire specialties and experienced National-Standard engineering service help meet your special requirements.

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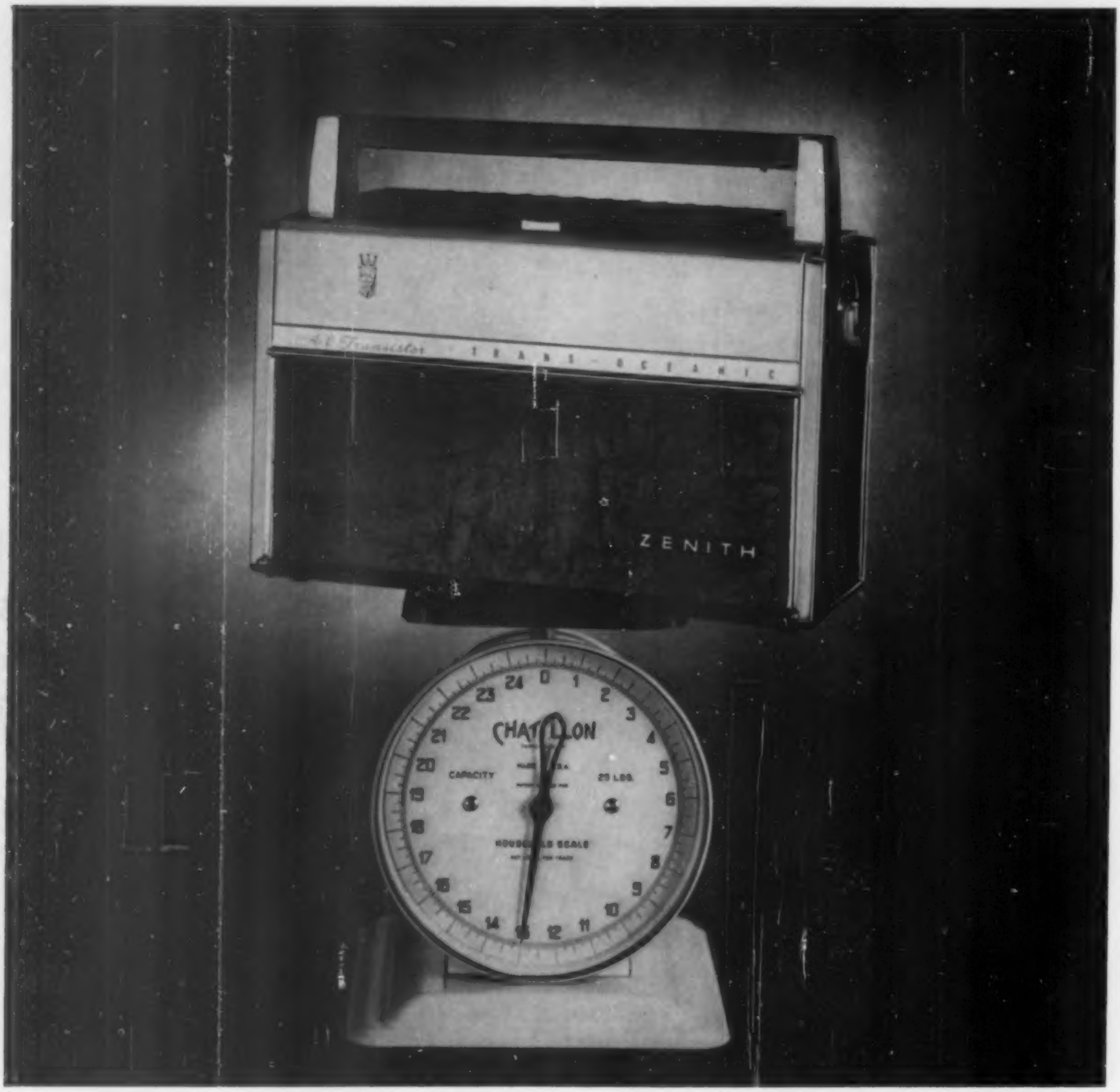


ASSIGNMENT: A weighty one. Take the Zenith Royal 1000 Transoceanic portable radio and pare off half of its 26 pounds—without reducing performance. How do you do it? With an aluminum case? No. With plastics? No. You do it with a housing made from eleven thin-wall, high strength zinc die castings. You do it with the only material and method that can provide the "as cast" tolerances necessary for the flush-fit the design demands. You rely on a material that can be cast thinner, and yet stronger, than any die casting competitor; a material whose castability permits shapes and intricate sections prohibitively expensive by other fabricating techniques. You know that assembly will be easy, because you can use self-tapping screws, and speed nuts on the cast bosses. You know that finishing will be a pleasure, with a smooth surface that readily accepts bright, satin and brush-finish chrome plate, as well as paint to fill the cast lettering. We could go on and on, detailing the advantages each one of the eleven zinc die castings demonstrates, pointing out the skillful designing that combines a multitude of functional and decorative duties. However, all you need do is look at the scales above and remember—zinc die casting gives you more for less. How else would you make it?

Zinc die castings by Paragon Die Casting Company, Chicago, Illinois.

NJZ

THE NEW JERSEY ZINC CO.
160 FRONT STREET • NEW YORK 38, N. Y.

MACHINE DESIGN
December 21, 1961

In the Driver's Seat

"WHERE did you learn to drive?" This question, embellished with colorful, obscene, and blasphemous adjectives, is the recognized opening gambit following a traffic incident.

Change the environment and a few words, and you have an all-too-frequent situation in business and industry. The manager or supervisor is in the driver's seat—and there bad drivers are just as hazardous to themselves and others as out on the highway. Only the discussion is much less open.

Too often the ambition and drive to become a manager are accepted in lieu of genuine talent. Result: Another bad driver.

Engineers, according to surveys reported by Gene Raudsepp overleaf, overwhelmingly believe that management offers higher prestige and income than does engineering. Therefore, those who attach importance to these things (and who doesn't?) are ambitious to get into the driver's seat.

Assuming he has the right temperament, personality, and motivations, the man who has been educated and employed as an engineer is better equipped for a management job than many men from other occupations.

True, he may have to learn how to make decisions without the backing of mathematical or experimental proof. But the engineering approach is a powerful asset he can bring to the management function.

But before becoming a licensed driver, a man practices and tests himself to be sure he can qualify. So before heading for the driver's seat in his section, department, division, or company, an engineer might consider testing himself with the aid of the quizzes in Mr. Raudsepp's article.

After all, there are good engineers who should never try to manage. Just as there are good cowboys who should never try to drive a car!

Colin Carmichael

EDITOR

STAY PUT OR TRANSFER

ENGINEERING
OR
MANAGEMENT

Here are tests which can help engineers decide for themselves.

EUGENE RAUDSEPP
Director of Psychological Research
Deutsch & Shea Inc.
New York, N. Y.

EVERY year, more and more administrative positions in industry are being filled by engineers. Every year, according to surveys, more and more engineers set their sights early on administrative or management careers. Although in many companies, engineers continue to gain professional recognition and can now advance in their line of work through the "parallel-paths" system of promotion, management, as a career, retains its appeal.

One survey, by Deutsch & Shea, found that nearly 80 per cent of 3000 engineers felt that more opportunity for advancement, both financially and in status, lies outside technical specialization. In another survey, by the Professional Engineers Conference Board for Industry, this is how 295 engineers responded to two questions:

Question: Suppose an engineer at your company were considering whether to stay strictly in engineering or to move into the management end of the business. Assuming proper qualifications for either field, do you think in five years he would be better off *financially* by staying in engineering or by going into management?

Engineering better	7 per cent
Management better	85
Same either way	6
No opinion	2

Question: In terms of *prestige* within the company, do you think this same individual would be better off in five years by staying in engineering or by going into management?

Engineering better	6 per cent
Management better	85
Same either way	7
No opinion	2

Obviously, the feeling is prevalent that salaries paid to management are substantially greater than salaries paid to technical men. Even where the parallel-paths advancement concept has adjusted engineers' salaries upward, the engineer still feels that salary ceilings are lower in the technical area than in management.

Lately, more attention is being paid to the engineering profession in the press and other mediums,

Circle 26-2 on Page 19 for extra copy.

but the engineer still tends to feel that this recognition is too little and too late.

Why Management Looks Good

Why do management positions continue to lure engineers?

For one thing, in many companies the parallel-paths concept of advancement has not gained foothold, and the only higher positions are still managerial. As one engineer puts it, "The company only pays lip service to the idea and policy that a scientist can advance in stature, pay, recognition, and prestige without getting into administrative work. Without getting out of actual research, there appears to be nowhere to go after about ten years of service." Managerial or administrative positions have long enjoyed prestige and acceptance by companies and communities. Engineering, on the other hand, is only now coming into its own.

Along with the parallel-paths advancement channels, many new and fancy titles have been coined. Experience with titles, however, has been discouraging. Although engineers are quite sensitive about their professional status, they don't put much stock in the titles that have been invented lately.

In many colleges and universities, the idea is widespread that pecuniary success and prestige lie in administration rather than in technical work. As Professor Lee E. Danielson, University of Michigan, points out, "Many (students) follow engineering programs only so that they will be more employable. Once employed, they actively seek to move out of the technical areas and into more lucrative ones such as management and sales."

It has also been suggested that the setting of sights on the managerial career may be due to engineers' inordinate ambition. As one engineer said in a study by Professor Danielson on engineering utilization and motivation, "All engineers are too ambitious. They all expect to get to the top even when they don't have the right qualifications. They don't realize that there are some people better qualified to handle big administrative jobs in the company."

A managerial or administrative position gives the engineer a sense of power. He will be able to exert greater influence and control over organizational objectives and subordinates. Power enhances self-esteem.

Many engineers feel that the levels of authority and responsibility in the administrative areas are better defined, while in engineering they frequently are given responsibility without corresponding authority.

Engineers also feel that ability and performance in management positions are valued and rewarded better than outstanding skill in technical areas.

Effects of the Trend

So the exodus to management ranks continues. Outstanding technical skill, when it gets rewarded, forms the shortest route to the administrative career, irrespective of the presence or absence of requisite administrative skills. If this exodus continues unchecked, and if no better selection in terms of requisite skills and aptitudes is made, several serious repercussions follow:

1. There will be further serious depletion of valuable technical manpower.
2. Effectiveness and utilization of engineers will be seriously reduced. No engineer can brood lovingly over his technical work, if one eye is roaming the greener pastures on the management side of the fence.
3. If the engineer is promoted into administration as a reward for high technical achievement or competence, but lacks managerial potential, the company loses one outstanding technical man and gains a poor manager. His poor handling of subordinates takes a further toll of human talent and hence also reduces the company's chances of success.

A substantial number of engineers in supervisory and management work, if they would admit it, would consider themselves engaged in work for which they are ill-suited, in which they have little or no interest, from which they derive only meager satisfactions, and which prevents them from utilizing their real talents and aptitudes fully.

Many regard themselves privately as failures. At first, a higher material well-being seemed to them to compensate for the sacrifice they made. Later, the extra money is taken more and more for granted and affords small comfort for the boredom and lack of personal technical challenge in their jobs. When an engineer's self-image and job roles do not match, dissatisfaction is apt to result.

Of course, there are other engineers whose choice of management work was felicitous and whose talents in the administrative line reap benefits for themselves and their companies.

Making Sure About Management

When an engineer decides to move into management, he is changing the course of his entire life. He should review his decision against personal abilities and interests, and the requirements of administration. The inventories which follow can help to determine whether the decision is sound.

The inventories are not intended to dissuade an engineer from deciding to follow a career in management. But they help to emphasize that if the engineer's reasons for seeking a managerial career are based mainly on the desire for increased salary and prestige, he should take a closer and harder look at his aspirations.

Bear in mind . . .

as you answer each question in these inventories, to look for confirming evidence. For example, you may feel that you can gain cooperation easily and that people often come

to you for advice. How often has this actually happened? Again, you may think that you have great leadership potential. Have there actually been occasions when you had to marshal this potential?

INVENTORY

NO. 1 Attitudes Toward Present Job

	Yes	No
1. Do you have any doubts about your future as a technical specialist?	☐	☐
2. Are these doubts due to your ability to perform, to achieve success and recognition in your field?	☐	☐
3. Do you find that your present work fails to satisfy you?	☐	☐
4. Do you think you would remain dissatisfied if you transferred to another department or accepted a new position in another company in the technical line?	☐	☐
5. Are there difficulties in your work which you find hard to overcome?	☐	☐
6. Are these difficulties due to the nature of your work rather than to the organizational and human elements in your company (e.g. supervision, red tape, union interference, etc.)?	☐	☐
7. Does time drag and do you catch yourself watching the clock frequently?	☐	☐
8. Are you frequently late to work or absent from it?	☐	☐
9. Are advancement opportunities limited in the technical area of your work?	☐	☐
10. Are there important abilities and skills you are not able to utilize in your present job?	☐	☐
11. Do you find that you do not get along with your supervisors and colleagues as well as you did in the past?	☐	☐
12. Have you wished you had taken more human relations and business courses while in college?	☐	☐

An abundance of checks under "Yes" indicates that you have to do some serious career planning.

INVENTORY

NO. 2 Implications of Change

Do you realize that . . .

Each promotion in the management hierarchy will involve you more and more with administrative tasks and less and less with technical work.

• • •

Frequently this decision to transfer is irrevocable. Chances are that after a few years away from the technical area, you won't be able to make a return even if you wanted to. The state of the art will advance so rapidly that it would take you years just to catch up.

• • •

You will move from relatively predictable area, where you can exercise control over what you are doing, into an area where both the human variables and business conditions are frequently uncontrolled.

• • •

Both your knowledge and interests have to broaden considerably and you won't be able to follow one particular interest.

• • •

You have turned your back to personal, professional achievement. Instead, your main satisfactions will flow from having progressively more control and power over people and activities, and from helping technical professionals to achieve success.

• • •

Merely observing the activities of those in administration may give you a misleading picture of what is involved.

INVENTORY NO. 3

Temperament and Interests

1. If you had your choice of two occupations other than the one you now have, which would you rather be?

   a. A physician ☐ b. An explorer ☐

2. Which would you rather read a book about?

   a. Geography ☐ b. Psychology ☐

3. How would you rather spend an evening?

   a. Building some new furniture in the workshop ☐

   b. Playing cards with a neighbor and his wife ☐

4. How patient are you when someone delays you?

   a. Always very patient ☐ b. Tend to get annoyed ☐

5. Which would you rather do?

   a. Meet a new person ☐ b. See a show ☐

6. Would you rather be known as . . .

   a. Co-operative ☐ b. Resourceful ☐

7. Do you like to have a place for everything and everything in its place?

   a. Important to me ☐ b. Not really important ☐

8. If you strongly disagree with another person, what do you do?

   a. Seek the most agreeable compromise with the least fuss ☐

   b. Argue out the difference in value, principle, or policy ☐

9. Is it easy for you to stop reading in the middle of an interesting story?

   a. Yes ☐ b. No ☐

10. In school and college, activities like drama, art, band, and debating had very little appeal to me.

    a. Yes ☐ b. No ☐

11. Do you tend to become moody and irritable when things do not work out according to plan or schedule?

    a. Yes ☐ b. No ☐

12. Which part would you rather have in a play?

    a. Teddy Roosevelt ☐ b. Albert Schweitzer ☐

Supervisory and management personnel tend to give the following responses: 1a, 2b, 3b, 4a, 5a, 6a, 7b, 8a, 9a, 10b, 11b, 12b.

INVENTORY NO. 4

Personality Traits

	High	Average	Below Average
Dependability	☐	☐	☐
Self-confidence	☐	☐	☐
Friendliness	☐	☐	☐
Tactfulness	☐	☐	☐
Cheerfulness	☐	☐	☐
Forcefulness	☐	☐	☐
Persistence	☐	☐	☐
Sense of humor	☐	☐	☐
Responsibility	☐	☐	☐
Loyalty	☐	☐	☐
Sincerity	☐	☐	☐
Frankness	☐	☐	☐
Ambitiousness	☐	☐	☐
Industriousness	☐	☐	☐
Co-operativeness	☐	☐	☐
Enthusiasm	☐	☐	☐
Open-mindedness	☐	☐	☐
Being a self-starter	☐	☐	☐
Leadership ability	☐	☐	☐
Determination	☐	☐	☐
Patience	☐	☐	☐
Aggressiveness	☐	☐	☐
Accuracy	☐	☐	☐
Judgment	☐	☐	☐
Self-sufficiency	☐	☐	☐
Cautiousness	☐	☐	☐
Orderliness	☐	☐	☐
Stability	☐	☐	☐
Conscientiousness	☐	☐	☐
Creativity	☐	☐	☐
Communications skill	☐	☐	☐
Organizational ability	☐	☐	☐
Resourcefulness	☐	☐	☐
Poise	☐	☐	☐
Persuasiveness	☐	☐	☐
Assertiveness	☐	☐	☐
Introspectiveness	☐	☐	☐
Adaptability	☐	☐	☐
Perfectionism	☐	☐	☐
Flexibility	☐	☐	☐
Argumentativeness	☐	☐	☐
Decision-making ability	☐	☐	☐
Synthesizing ability	☐	☐	☐
Ingenuity	☐	☐	☐
Tolerance for intangibles	☐	☐	☐
Sensitivity to people	☐	☐	☐
Work enthusiasm	☐	☐	☐
Emotional control	☐	☐	☐
Tolerance for complexity	☐	☐	☐
Social intelligence	☐	☐	☐

Effective supervisors rate "high" in the following traits: Dependability, friendliness, tactfulness, responsibility, loyalty, sincerity, co-operativeness, open-mindedness, leadership ability, patience, judgment, stability, communication skills, organizational ability, persuasiveness, adaptability, flexibility, decision-making ability, tolerance for intangibles, sensitivity to people, work enthusiasm, emotional control, tolerance for complexity, and social intelligence. Aspirants to management positions should rate "high" in at least 15 to 18 of those traits.

INVENTORY NO. 5

Supervisory Principles

	Agree	Don't Agree
1. Engineers have pretty much uniform personality traits and needs; they are motivated according to a single pattern, and should be treated pretty much alike.	☐	☐
2. The most important recognition for an engineer is more money.	☐	☐
3. Leadership ability is in-born; one can do little to develop it.	☐	☐
4. Most engineers are interested in working on projects that bring them recognition among their peers.	☐	☐
5. An effective supervisor is able to size up an engineer the first time he meets him.	☐	☐
6. Lack of challenge and interest accounts for listlessness, loafing, and grumbling, rather than inherent laziness.	☐	☐
7. Long acquaintance with an engineer enables the supervisor to predict what he will do in any given situation.	☐	☐
8. Engineers' attitudes toward a company are difficult or impossible to change.	☐	☐
9. Engineers' output does not depend on what attitudes they have toward management and toward the company.	☐	☐
10. The supervisor should not pay any attention to engineers' feelings.	☐	☐
11. The supervisor should not praise engineers for a good piece of work, for then they will become difficult to handle and insist on immediate salary raises.	☐	☐
12. The supervisor should not be expected to coach and train engineers; most of his energies should go into running his department.	☐	☐
13. The most effective way to get increased work-performance from an engineer is to instill in him a fear that he can lose his job any time.	☐	☐
14. A team of engineers can always solve problems better than one engineer can.	☐	☐
15. An effective supervisor should be as adept in each man's specialty in his group as are the men themselves.	☐	☐
16. Knowing the personality traits of each member in the group goes a long way in staving off morale problems.	☐	☐
17. The supervisor does not have to explain to his group the reasons for management decisions or changes in company policies.	☐	☐
18. The supervisor should be skilled in the arts of coaching and teaching.	☐	☐
19. High salaries and generous fringe benefits are the two most important motivating factors for the engineer.	☐	☐
20. If the supervisor does not know the answer to an engineer's question he should say: "I don't know the answer, but I'll find out and let you know."	☐	☐

	Agree	Don't Agree
21. In making a decision concerning engineers' work the supervisor should always have them participate in the decision making.	☐	☐
22. Engineers would not have much respect for a supervisor who asks them for suggestions.	☐	☐
23. Self understanding is just as important as is understanding others.	☐	☐
24. The supervisor should not show too much friendliness and consideration toward engineers, for they might then think him "soft."	☐	☐
25. The supervisor should make sure that a really efficient and capable engineer stays in his department.	☐	☐
26. The effective supervisor is more staff-oriented than management-oriented.	☐	☐
27. Close supervision of engineers produces the best results.	☐	☐
28. When an engineer has problems, he should try to keep them to himself and solve them as best he can, rather than take the supervisor's valuable time.	☐	☐
29. One of the important tasks of the supervisor is to "sell" his people to top management.	☐	☐
30. The supervisor should follow his superior's directives without questioning, even when he disagrees with them or thinks that they are wrong.	☐	☐
31. Criticism and discipline bring better results than does praise.	☐	☐
32. The supervisor can do little to improve engineers' morale because he has to work within strict company policy and rules.	☐	☐
33. The supervisor would do well not to delegate any authority to the engineers working under him.	☐	☐
34. It is very important to recognize the contributions of each engineer individually, rather than praise the team he is a member of.	☐	☐
35. Engineers require "individualized" attention.	☐	☐
36. The supervisor of technical professionals can rely on methods of supervision that have proved successful with other occupational groups in other parts of the company.	☐	☐
37. To serve as a source of information and a source of relief from frustrations is one of the more important supervisory functions.	☐	☐
38. Engineers should be kept well informed about the objectives of the company and the reasons behind higher management's actions.	☐	☐

According to the latest human relations techniques and supervisory practices of technical professionals, the "correct" answers are:

1. DA	11. DA	21. A	31. DA
2. DA	12. DA	22. DA	32. DA
3. DA	13. DA	23. A	33. DA
4. DA	14. DA	24. DA	34. A
5. DA	15. DA	25. DA	35. A
6. A	16. A	26. A	36. DA
7. DA	17. DA	27. DA	37. A
8. DA	18. A	28. DA	38. A
9. DA	19. DA	29. A	
10. DA	20. A	30. DA	

You should score at least 80 per cent right to be able to say that you have the "feel" for supervisory principles.

INVENTORY NO. 6

Checking Your Decision To Go into Management

After you have made your decision to switch into administration, ask yourself these questions:

1. Is your decision compatible with your own aptitudes, interests, personality, character, and objectives in life? Does it offer more opportunity to exercise your abilities than does your present job? Would you select it, without qualification, as your life's work?

2. Are you sure you are well fitted for it, that you possess sufficient abilities and necessary qualifications for it? Are your expectations of your future in management realistic?

3. Are you sure you will derive greater personal and psychological satisfaction from the administrative type of job?

4. How thorough is your knowledge of the company's operations? Are you familiar with the different standards and administrative procedures that exist in different departments of your company? How easy do you think it will be for you to follow them or switch flexibly from one to the other? How familiar are you with the other phases of your company's operations?

5. Have you mapped your goals five or ten years from now? What is your avenue of approach for the attainment of these goals? Are you sure your new line of work will best contribute to the attainment of these goals? Do you realize that in the management hierarchy, an even stiffer competition and a more limited number of opportunities for advancement exist? Are you sure you can meet this competition adequately?

6. Are your interests more "people-oriented" than "thing-oriented?" Do you like to be and work with others rather than alone? Can you gain co-operation easily? Do you volunteer to help others? Are you curious to know what makes people behave the way they do?

7. Are you considered friendly and congenial by people on and off the job? If it means some personal sacrifice, does it take real effort on your part to go out of your way to help another person? Do people come to you for advice? How often? Do people feel at ease when talking with you? Do you yourself frequently move about and exchange ideas with others? Do you willingly ask others to help you clarify your own problems?

8. Are you flexible to changing conditions? Can you tolerate ambiguous and uncertain situations well? Do you become bothered by situations where all the facts are not available or can not be marshalled when they are needed? Do you feel uneasy when it is quite uncertain what the outcome of your decisions will be?

9. Do you have insight into your own motives, values, and needs? Do you know what impact you have on others? Are you sensitive to the effects which people have on one another? Do you feel you can trust others and that others can trust you? Can you readily allay suspicion?

10. Do you have a highly developed sensitivity toward the human and subjective factors in work situations? How sensitive are you to the needs of your associates? Would you retain this sensitivity toward your subordinates?

11. Will you find greater satisfaction in directing and developing your subordinates rather than pursuing a strictly technical career?

12. Have there ever been situations where you were called upon to show leadership abilities? What happened and how did you perform?

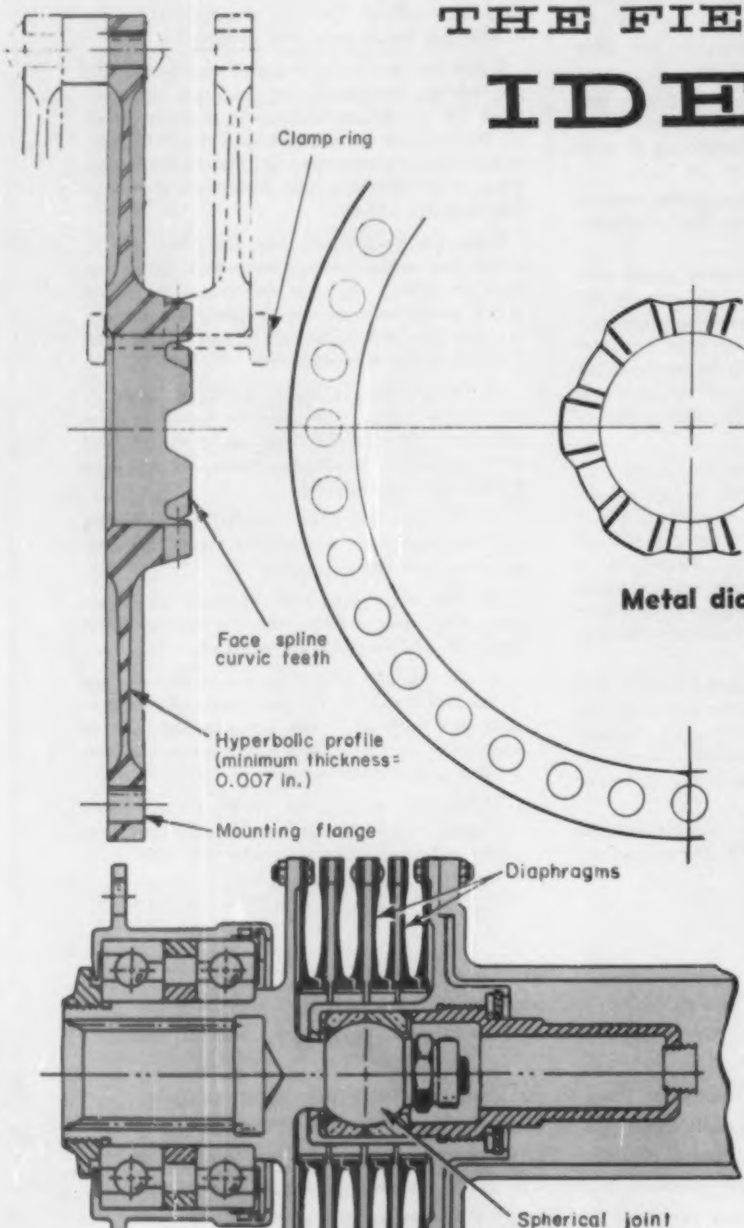
13. Do you take note of your own behavior and try to understand it? Do you occasionally listen to your own words as if from someone else's point of view? Do you search for the way things look from another person's point of view?

14. Do you feel you can readily contact people in widely varying stations of life? Do you treat others as persons beyond the roles they take?

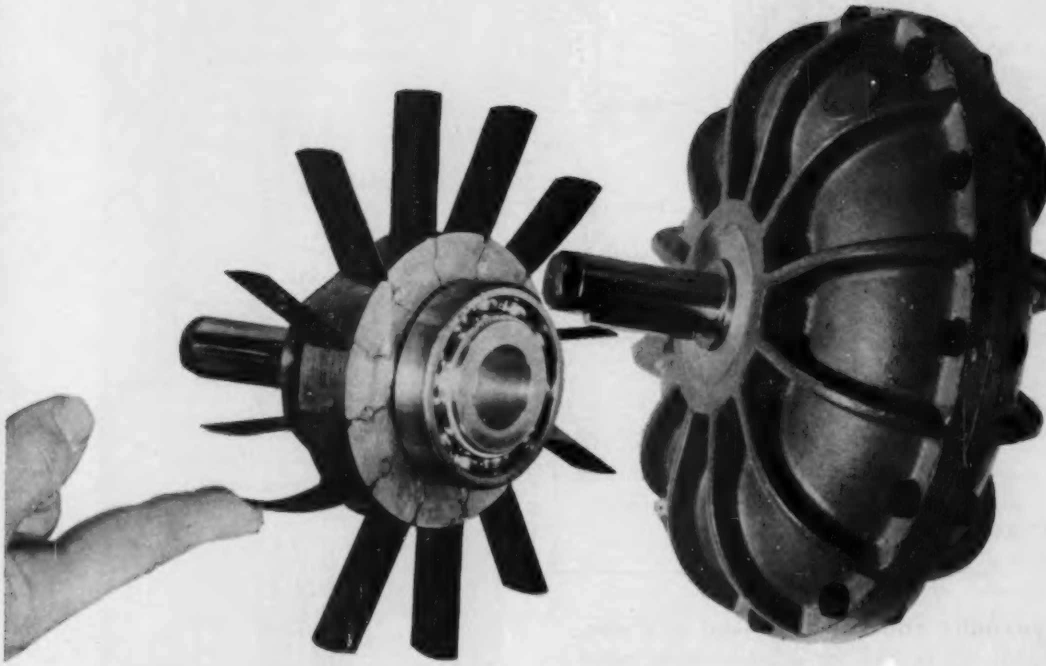
If, through this soul-searching you become fully resolved that you have administrative potential, your next step is to map a program of how you can best develop this potential.

When you attain the first rung in the management ladder, as an engineering supervisor, occasionally read this statement (from George S. Trimble, Jr., in Martin Company's Appraisal Guide), "As an engineering supervisor, you are in command of the most precious energy on earth—human thought. Your success is a funtion of how much of this energy you can bring out of each of your people and how well you direct its use. Sometimes it is difficult to tell how much capacity an individual has for producing this energy and still more difficult to tell just how he is using his output. But it is a safe bet that every individual is capable of doing better than he has ever done before."

SCANNING THE FIELD FOR IDEAS

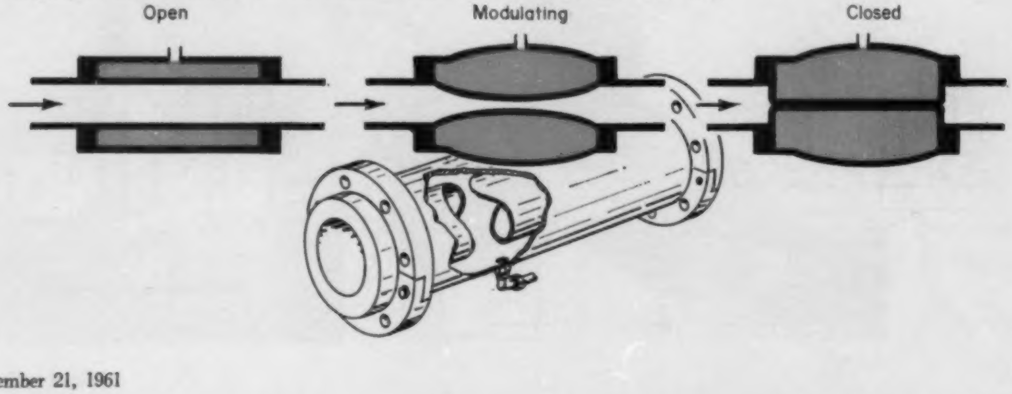


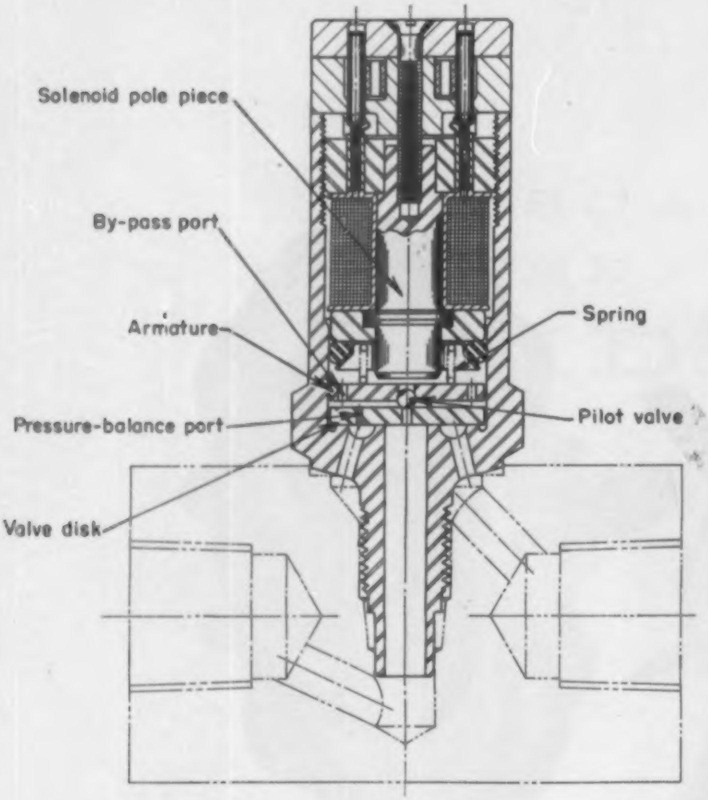
Metal diaphragms transmit torque in a constant-velocity universal-joint type coupling. Diaphragm pairs are connected by face splines at the ID of the diaphragms. Hyperbolic profiles across the flexing face of the diaphragms provide substantially uniform stresses in both torsion and bending. Principle employed in a coupling designed by Bernard Goldberg and Henry Troeger, Utica Div., Bendix Corp., Utica, N. Y.

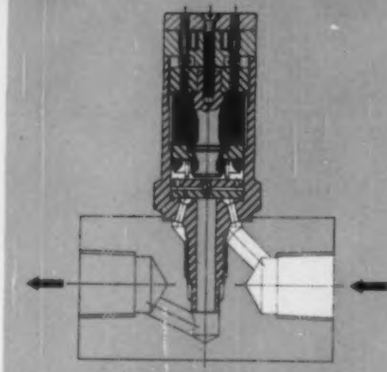


Flexible blades limit torque in a hydraulic coupling. During normal operation, the input-driven housing delivers torque through the fluid ring formed by centrifugal force to the blades attached to the output shaft. When torque load exceeds a preset value, the steel blades deflect to limit torque without overheating the oil. Principle employed in a hydraulic coupling by Societa Generale Delle Macchine Mill, Milan, Italy.

Concentric hoses form valve which can be operated by externally applied pressure for flow control or shut-off. Length of the flexible valve permits it to profile around any solid particles trapped in the valve. Principle employed in a valve by D. M. Connor and Co., South Plainfield, N. J.



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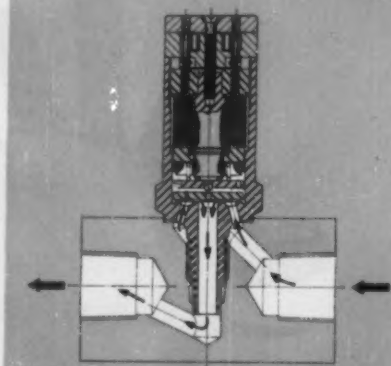
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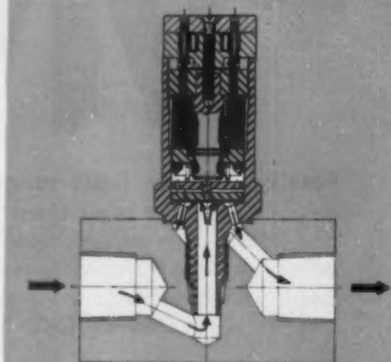
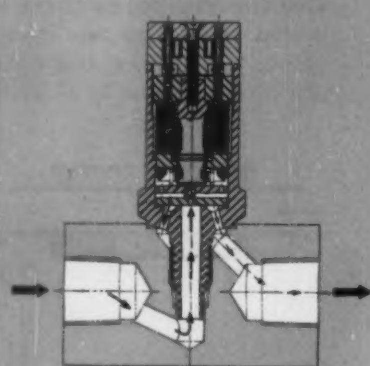
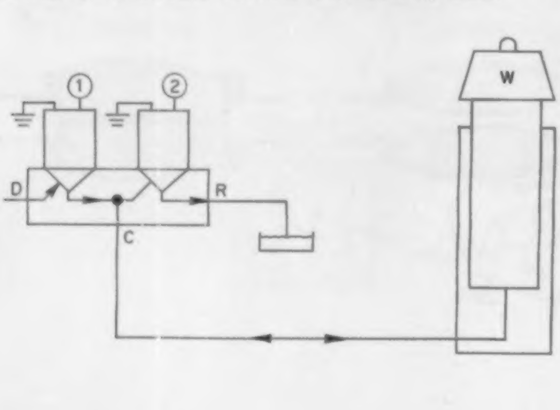
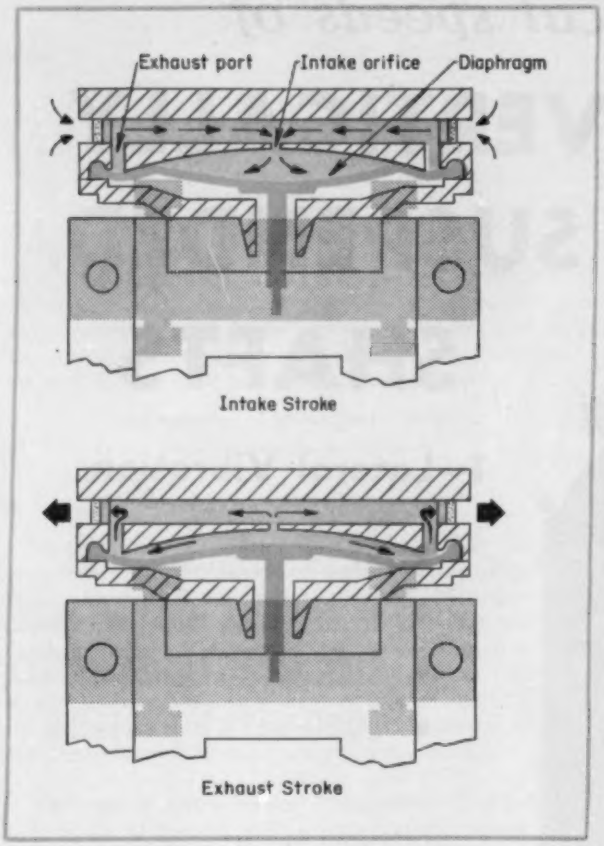

Normally open (open)


Normally open (closed)

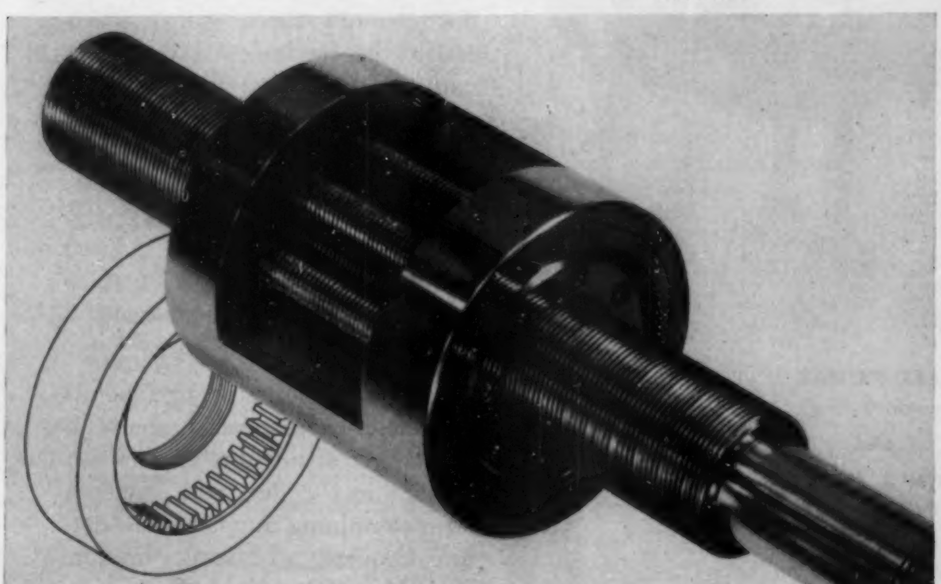
Reversible hydraulic control is provided by a pilot-operated valve which can be used for either normally closed or normally open operation. In the normally closed arrangement, the spring-loaded pilot valve is closed, thus permitting the line pressure to hold the valve disc closed. When the solenoid is energized, the pilot valve opens, and line pressure opens the valve disc. In the normally open arrangement, the valve disc is held open by line pressure. The armature does not contact the solenoid pole piece, and the pilot valve remains on its seat. When the solenoid is energized, the armature moves the remaining small distance to the pole piece. The pilot valve opens and permits pressure build-up which closes the disc. Flow through the pressure-balance port produces a slight closed-valve leakage. Principle employed in a miniature control valve by SPARD Div., Electric Autolite Co., Toledo, Ohio.





Diaphragm replaces valve in a pneumatic timing relay. During the intake stroke, the outer edge of the diaphragm seals the exhaust ports, forcing the incoming air to enter through the orifice. During the exhaust stroke, air pressure breaks the seal of the outer edge to open the exhaust ports. Principle employed in a timing relay by Cutler-Hammer Inc., Milwaukee, Wis.

Helical roller bearings support load in a low-friction screw-nut actuator. Internal gear teeth in the actuator body mesh with teeth on the end of the rollers to insure synchronized rotation of the rollers. Principle employed in an actuator by La Technique Integrale, Paris, France.



Critical speeds of

VERTICALLY SUSPENDED SHAFTS

1—Lateral Vibration

- BASIC ASSUMPTIONS
- NEGLIGIBLE DISC EFFECT
- SIGNIFICANT DISC EFFECT
- EQUIVALENT SYSTEMS

ALEX PRIMAK
Engineering Analyst

and

ERWIN J. NUNLIST
Product Development Engineer

Pfaudler Div.
Pfaudler Permutit Inc.
Rochester, N. Y.

Critical speed in a rotating system is the speed at which the frequency of induced vibration is the same as the natural frequency of the system. In practice, it is usually defined as the operating speed (rpm) which equals the fundamental or lowest natural frequency (cpm). At this speed, vibration is self perpetuating, and the resulting large deflections may create destructive stresses. Dangerous conditions may also occur if the frequency of induced vibration is a simple fraction or multiple of the fundamental natural frequency.

How to find these danger points in vertically suspended shafts is the subject of this three-part series. Parts 1 and 2 deal with methods for determining fundamental natural frequency of lateral vibration. Part 3 covers torsional vibration.

ALL rotating systems have some imbalance. Centrifugal forces produced by this imbalance will eventually induce vibrations which may be transmitted to stationary parts. To keep vibration from exceeding safe levels, operating speeds near the critical-speed range for the system must be avoided. Key factors to be considered in design are:

1. Natural frequency of lateral (beam) vibration
2. Natural frequency of torsional vibration
3. Stresses
4. Deflections

In this three-part series, which deals with the properties of suspended vertical shafts, primary attention is focused on the first two factors. This article presents analytical methods for determining the fundamental natural frequency of lateral vibration. A simplified, graphical technique is outlined in Part 2, which also examines the effect of support elasticity on the accuracy of calculated results. Methods of torsional-vibration analysis are given in Part 3.

The type of system under consideration employs a vertically suspended shaft mounted at the centers of two frictionless, absolutely rigid bearing supports. Bearings are selfaligning and operate without restriction on the vibrating shaft. Effects of potential energies due to gravitational forces and axial tension are disregarded.

In this discussion, disc refers to all types of symmetrical rotating loads that are rigidly attached to the shaft; such as agitators, impellers, etc.

• BASIC ASSUMPTIONS

For this analysis of lateral vibration, initial assumptions are:

1. Shaft axis is straight before deformation.
2. Small displacements at any point are in a direction perpendicular to the shaft axis.
3. Deflections do not exceed the elastic limit.
4. No external disturbing forces or torques are present, so that harmonic vibrations are due only to initial displacements.

Natural frequency is defined here as the frequency of free vibration maintained by elastic forces only, with or without damping. Therefore, the natural frequency depends on the elastic characteristics of the shaft material; shape and size of the shaft; attached masses; and method of support.

The natural frequency of rotating and stationary shafts are somewhat different. However, in most cases, it is permissible to use the static condition as a basis of analysis.

• NEGLIGIBLE DISC EFFECT

Consider an elastic, weightless, suspended shaft which carries several rigidly attached discs, Fig. 1, having relatively small mass moments of inertia. To obtain fundamental natural frequency of free vibration of such a system, the energy method with the Rayleigh approximation will be used.

If the dynamic-deflection curve of the vibrating shaft in the extreme position is assumed to be the same as the static-deflection curve (due to gravitational forces), and the harmonic motion of the discs is defined by

$$y_i = \delta_i \sin(\omega_n t + \varepsilon)$$

where subscript i is the generalized case ($i = 1, 2, 3,$ etc.), then the potential energy stored in the deflected shaft is:

$$\mathrm{PE} = \frac{1}{2} W_1 \delta_1 \sin(\omega_n t + \varepsilon) + \ldots +$$

$$\frac{1}{2} W_n \delta_n \sin(\omega_n t + \varepsilon) +$$

$$\frac{3}{4} \sum_{i=1} W_i \int_0^{a_i} \left(\frac{dy}{dx} \right)^2 dx$$

The last term represents the gravitational and tensional effect. Since this effect usually has only negligible influence on the natural frequency it will be disregarded in this discussion.

Kinetic energy of the vibrating discs is:

$$\mathrm{KE} = \frac{1}{2} \frac{W_1}{g} \delta_1^2 \omega_n^2 [\cos(\omega_n t + \varepsilon)]^2 + \ldots +$$

$$\frac{1}{2} \frac{W_n}{g} \delta_n^2 \omega_n^2 [\cos(\omega_n t + \varepsilon)]^2 +$$

$$\frac{1}{2} \sum_{i=1} J_{em} \left(\frac{dy_i}{dx} \right) \omega_n^2 [\cos(\omega_n t + \varepsilon)]^2$$

where the last term is important only for slender shafts.

As these energy expressions show, when the po-

tential energy during vibration is a maximum, the kinetic energy equals zero, and vice versa. Thus, when a system is acted upon by elastic forces, and dissipated energy is neglected, the system may be considered conservative. Based on the principle of conservation of energy, maximum potential energy equals maximum kinetic energy. Equating these two quantities gives the following expression for the fundamental or lowest natural frequency of system:[1]

$$f_n = \frac{60}{2\pi}\,\omega_n = 187.7\left(\frac{\sum_{i=1} W_i\delta_i}{\sum_{i=1} W_i\delta_i^2}\right)^{1/2} \quad (1)$$

Thus, to calculate fundamental natural frequency of lateral vibration, only the static deflections of the shaft are needed. However, if the rigidly attached discs have relatively large mass moments of inertia, the gyroscopic effect may influence the fundamental natural frequency.

• SIGNIFICANT DISC EFFECT

Consider an elastic, weightless, suspended shaft with several rigidly attached symmetrical discs, Fig. 1, which have high mass moments of inertia. If the geometric axis of the uniform disc coincides with the axis of the revolving shaft, the disc has the gyroscopic characteristic of a spinning body to retain the direction of the axis of rotation.

In this situation, the deflection curve of the revolving shaft will depend upon both the centrifugal forces and the gyroscopic moments.

When the discs are considered as symmetrical gyroscopes having the same angular velocity and direction of precession as the shaft, approximate magnitude of the gyroscopic moment is[1]

$$M_g = -(J_{am} - J_{em})\omega^2\phi_m \quad (2)$$

Effect of gyroscopic action is to reduce the shaft deflection due to centrifugal force.

At critical speed ($\omega = \omega_n$), the applied forces on the shaft are in equilibrium with the reactive elastic forces. If the shaft-deflection curve corresponding to the fundamental mode of vibration is assumed to be of the same form as the static-deflection curve (Rayleigh approximation), then the natural frequency under gyroscopic action is

$$f_n = 187.7\left[\frac{\sum_{i=m} W_i\delta_i}{\sum_{i=m} W_i\delta_i^2 - g\sum_{i=m}(J_{am} - J_{em})\phi_m^2}\right]^{1/2} \quad (3)$$

Thus, as this equation shows, when $J_{am} > J_{em}$ the rigidly attached symmetrical disc will stiffen the rotating shaft, increasing fundamental natural frequency. A kinematically unsymmetrical, rigidly attached disc (such as a two-blade impeller) will also increase fundamental natural frequency; however, the pulsating moment, which has a frequency of double the operating speed, may induce high stresses in the connected parts.

For relatively slender shafts with rigidly attached heavy discs which have large mass moment of inertia, gyroscopic action may have a significant effect on fundamental natural frequency. However, for shafts with attached discs or couplings having small mass moments of inertia, the influence of gyroscopic effect is usually negligible. For example, all industrial agitator applications usually involve rigid agitator shafts

[1]References are tabulated at end of article.

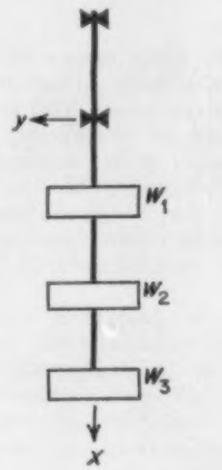


Fig. 1—Vertically suspended shaft with two bearing supports and discs, or rotors, rigidly attached to overhung section.

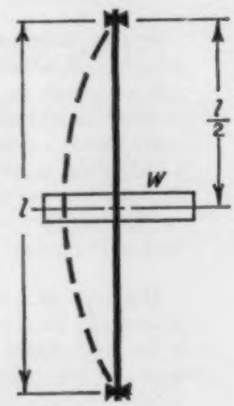


Fig. 2—Simply supported shaft with concentrated load at the midpoint.

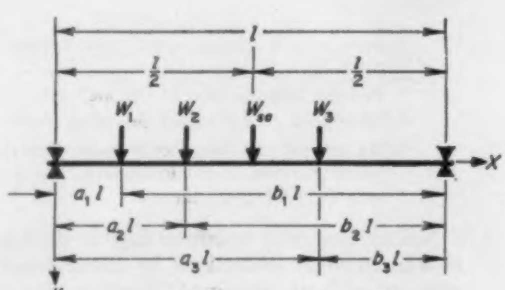


Fig. 3—Uniform-section shaft with three concentrated loads and the equivalent shaft weight concentrated at the midpoint of the span.

and, as a result, gyroscopic effect need not be considered. If the rotating system is such that gyroscopic effect can be ignored, Equation 3 reduces to the simpler expression given by Equation 1.

• EQUIVALENT SYSTEMS

A simply supported shaft, Fig. 2, carrying a concentrated load W at its center, is a system with n degrees of freedom. Assume the system is conservative. Then, for ease in analysis it may be reduced to a dynamically equivalent system, having one degree of freedom. This reduction is based on the principle that potential and kinetic energies are the same for both complicated and reduced systems.

Assume that the elastic line (deflection curve) of the rotating shaft in the extreme position is of the same form as the static-deflection line due to an arbitrary force P. Assume also that $W > W_s$. If δ_{max} is the maximum static deflection due to force P, deflection δ_x at any point along the shaft is:

$$\delta_x = \frac{x}{l^3}(3l^2 - 4x^2)\delta_{max}$$

Equating the maximum potential energy from bending to the maximum kinetic energy of the vibrating shaft weight and the concentrated load gives

$$f_n = \frac{187.7}{l}\left[\frac{48EI}{l(W_{se} + W)}\right]^{1/2} \qquad (4)$$

where equivalent shaft weight $W_{se} = (17/35)\ W_s = 0.486\ W_s$.

Thus, to find the fundamental natural frequency of the system with n degrees of freedom, the system may be considered as one with a single degree of freedom if total shaft weight W_s is replaced by an equivalent concentrated load, $0.486\ W_s$, applied at the midpoint of the shaft.

Assume now that $W_s > W$, and that the elastic line of the shaft during vibration has the same shape as the static-deflection curve due to uniformly distributed shaft weight. Under these conditions, equivalent shaft weight $W_{se} = (31/63)\ W_s = 0.492\ W_s$ instead of $0.486\ W_s$.[1]

Therefore, either of the static deflection curves ($W_s > W$ or $W_s < W$) may be used to find the fundamental natural frequency. Based on standard beam-deflection expressions, Equation 4 reduces to:

$$f_n = 187.7\left(\frac{1}{\delta_{se} + \delta_W}\right)^{1/2}$$

where δ_{se} and δ_W are static deflections due to the equivalent shaft weight and the concentrated load, respectively. At this point, the von Dunkerley[2] approximate method for establishing fundamental natural frequency may be used. This method holds for shafts of uniform or variable cross section.

The von Dunkerley approximation, in combination with the method of replacing shaft weight by an equivalent concentrated load, may be extended also to shafts subjected to several loads. Thus, for a uniform-section shaft, Fig. 3, with loads W_1, W_2, and W_3, and with the equivalent shaft weight W_{se} concentrated at the midpoint of the span,

$$f_n = \frac{187.7}{l}\left(\frac{3EI}{Z_3}\right)^{1/2}$$

where

$$Z_3 = l\left[\frac{W_{se}}{16} + W_1(a_1 b_1)^2 + W_2(a_2 b_2)^2 + W_3(a_3 b_3)^2\right]$$

and $W_{se} = 0.486\ W_s$, a_1, a_2, a_3 = ratios of load

Nomenclature

- a = Length of overhung shaft span, in.
- b = Length of intermediate shaft span, in.
- c = Distance from bottom bearing to disc attached at intermediate point on overhung shaft section, in.
- E = Modulus of elasticity, psi
- f_n = Fundamental natural lateral frequency of shaft system, cpm
- g = Gravitational acceleration, in./sec/sec
- I_i = Sectional moment of inertia, in.^{4}
- J_{am} = Polar mass moment of inertia (about the axis of rotation) of disc, lb-in.-sec^2
- J_{em} = Equatorial mass moment of inertia (about a diameter, or the transverse axis) of disc, lb-in.-sec^2
- l = Length of shaft span between bearings, in.
- M_g = Gyroscopic moment on shaft produced by rotation of disc, lb-in.
- m = Moment of inertia ratio, overhung span to bearing span $= I_1/I_2$
- q = Moment of inertia ratio, overhung span to intermediate span $= I_1/I_o$
- t = Time, sec
- W_i = Concentrated weight (disc), lb
- W_a = Weight of overhung shaft span, lb
- W_b = Weight of intermediate shaft span, lb
- W_d = Weight of shaft span between bearings, lb
- W_s = Total weight of shaft, lb
- W_{sa}, W_{sb} = Equivalent weights of overhung and intermediate shaft spans, respectively, lb
- x = Vertical co-ordinate of point on shaft measured from bottom bearing as reference, in.
- y_i = Displacement or deflection of any point on shaft, measured from centerline of bottom bearing as a reference, in.
- δ_i = Static deflection of any point on shaft in extreme postion, in.
- δ_{max} = Maximum static deflection, or vibration amplitude, of any point on shaft, in.
- ϵ = Phase angle, rad
- ϕ_m = Slope of shaft-deflection curve at the point of disc attachment, rad
- ω = Angular velocity, rad/sec
- ω_n = Fundamental natural frequency of lateral vibration, rad/sec

distance from left bearing to total span l; and b_1, b_2, b_3 = ratios of load distance from right bearing to total span l.

The method of replacing the shaft weight by a concentrated equivalent load is not applicable when a system is subjected to a pulsating force. When the cross section of the shaft is not uniform but varies irregularly, and only the principal natural frequency has to be determined, the graphical method of analysis is advisable (See *Part* 2 for details of this method).

The previous concepts and assumptions for static-deflection curves and equivalent systems can be applied to an elastic shaft with overhung weight. Three situations are considered here:

1. Uniform shaft cross section.
2. Overhung section with smaller moment of inertia than that of the bearing span.
3. Overhung section with larger moment of inertia than that of the bearing span.

Shaft mounting arrangements and basic equations for the three conditions are summarized in Table 1.

Uniform Shaft Cross Section: Case 1 in Table 1 represents a shaft of uniform cross section with a concentrated weight on its end in a state of free lateral vibration. Since the fundamental natural frequency does not conform very closely to the shape of the actual deflection curve, it may be assumed that the static deflection curve of the shaft is due only to an arbitrary force P applied at the overhung end. Thus, the system is reduced to one having a single degree of freedom. Obviously, this assumption is limited to shafts where: 1. The overhang is longer than the bearing span. 2. The concentrated load applied at the overhung end is larger than the shaft weight. However, this assumption will provide sufficiently accurate results in situations where the concentrated load in the overhang is smaller than the shaft weight.

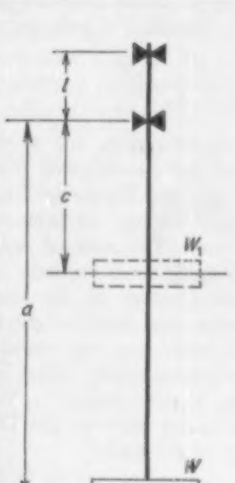


Fig. 4—Shaft of general form shown in Case 1, Table 1, with second disc attached to intermediate point along overhung section.

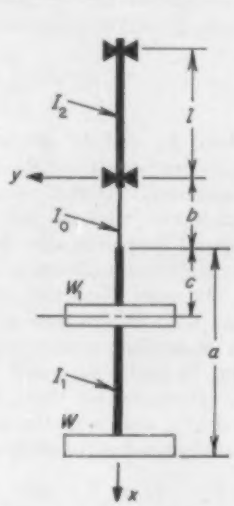


Fig. 5—Shaft of general form shown in Case 3, Table 1, with second disc attached to intermediate point along overhung section.

Maximum static deflection, Table 1, is based on an overhung beam which has an arbitrary force P applied at the overhung end. The general frequency expression is then found, as before, by equating maximum potential and kinetic energies (conservative system). As the general frequency expression shows, the shaft weight, W_d, in the bearing has only negligible influence on the natural frequency, and can be disregarded. Omitting this term gives the simplified equation.

The equivalent shaft weight, W_{sa}, represents the fraction of the weight of the shaft overhang which must be added to the concentrated weight at the end of the weightless shaft. Thus, to determine the principal natural frequency in this case, the equivalent weight of the overhang is added to the concentrated load and the shaft is assumed to be weightless. In the equivalent-weight expression, note that as length l is decreased, the fraction of weight W_a added to concentrated load W approaches 33/140, which is the condition for cantilever beams.

If the weight of the overhang is negligible, the equations in Table 1 are reduced to those given previously for weightless shafts. The principal natural frequency obtained with the simplified expression, Table 1, will be somewhat higher than that calculated by the classical method. For a shaft in which $a = 2l$ and $W_a = 2\,W$, the difference in frequency values calculated by the two methods is approximately 1.5 per cent.

When two discs are attached to the shaft, Fig. 4, the first or lowest natural frequency can be calculated by applying the von Dunkerley approximation. Equivalent shaft weight W_{sa} is determined as before (Case 1, Table 1). Then, based on the von Dunkerley approximation, combined frequency f_n is

$$f_n = 187.7\left(\frac{1}{\delta_{sa} + \delta_W + \delta_{W1}}\right)^{1/2} \tag{5}$$

where δ_{sa}, δ_W, and δ_{W1} are the deflections produced by W_{sa}, W, and W_1, respectively, at their points of application. From Equation 5, substituting appropriate values for the three deflections,

$$f_n = \frac{187.7}{a} \times \left[\frac{3EI}{(a+l)(W_{sa}+W) + (c+l)W_1\left(\frac{c}{a}\right)^2}\right]^{1/2} \tag{6}$$

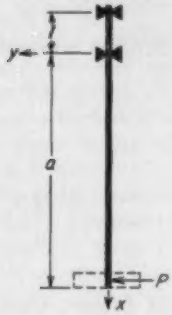
Effect of gyroscopic action is given by Equation 3.

Small Overhung Moment of Inertia: Case 2 in

Table 1—Basic Equations for Overhung Shaft Arrangements

Shaft System	Basic Equations

Case 1—Uniform Shaft Cross Section



Maximum Static Deflection

$$\delta_{max} = \frac{Pa^2}{3EI}(a + l)$$

General Frequency Expression

$$f_n = \frac{187.7}{a}\left[\frac{3EI}{(a+l)\left\{W_{sa} + W_d \dfrac{8}{420\left(\dfrac{a}{l}\right)^2\left(1+\dfrac{a}{l}\right)^2} + W\right\}}\right]^{1/2}$$

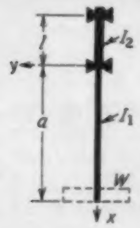
Simplified Frequency Expression

$$f_n = \frac{187.7}{a}\left[\frac{3EI}{(a+l)(W_{sa}+W)}\right]^{1/2}$$

Equivalent Overhung Weight

$$W_{sa} = W_a \frac{140l^2 + 231al + 99a^2}{420(a+l)^2}$$

Case 2—Small Overhung Moment of Inertia



Maximum Static Deflection

$$\delta_{max} = \frac{Pa^2}{3EI_1I_2}(aI_2 + lI_1) = \frac{Pa^2}{3EI_1}(a + lm)$$

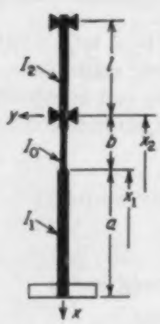
Simplified Frequency Expression

$$f_n = \frac{187.7}{a}\left[\frac{3EI}{(a+lm)(W_{sa}+W)}\right]^{1/2}$$

Equivalent Overhung Weight

$$W_{sa} = W_a \frac{140l^2m^2 + 231alm + 99a^2}{420(a+lm)^2}$$

Case 3—Large Overhung Moment of Inertia



Maximum Static Deflection

$$\delta_{max} = \frac{P}{3EI_1}\left[a^3 + lm(a+b)^2 + ba^2q\left(3 + 3\frac{b}{a} + \frac{b^2}{a^2}\right)\right]$$

Simplified Frequency Expression

$$f_n = \frac{187.7}{a} \times$$

$$\left[\frac{3EI_1}{\left\{a + lm\left(1+\dfrac{b}{a}\right)^2 + bq\left(3+3\dfrac{b}{a}+\dfrac{b^2}{a^2}\right)\right\}(W_{sa} + W_{sb} + W)}\right]^{1/2}$$

Equivalent Weight of Overhung Section

$$W_{sa} = W_a \frac{Z_1}{420a\left[a + lm(a+b)^2 + bq\left(3 + 3\dfrac{b}{a} + \dfrac{b^2}{a^2}\right)\right]^2}$$

where

$$Z_1 = (a+b)\left[140l^2m^2\left(1 + 4\frac{b}{a} + 6\frac{b^2}{a^2} + 3\frac{b^3}{a^3}\right) + \right.$$

$$210lbmq\left(4 + 11\frac{b}{a} + 11\frac{b^2}{a^2} + 4\frac{b^3}{a^3}\right) + 21lm(11a + 15b) +$$

$$\left.315b^2q^2\left(4 + 6\frac{b}{a} + 5\frac{b^2}{a^2} + \frac{b^3}{a^3} + \frac{b^4}{3a^3(a+b)}\right)\right] +$$

$$21bq(39ab + 15b^2 + 33a^2) + 99a^3$$

Equivalent Weight of Intermediate Section

$$W_{sb} = W_b \frac{Z_2}{420ab\left[a + lm\left(1 + \dfrac{b}{a}\right)^2 + bq\left(3 + 3\dfrac{b}{a} + \dfrac{b^2}{a^2}\right)\right]^2}$$

where

$$Z_2 = \frac{b^3}{a^3}\left\{(a+b)[140l^2m^2(a+b) + 21lbmq(15a + 11b) + \right.$$

$$\left.3b^2q^2(63a + 28b)] + 15b^4q^2\right\}$$

Table 1 represents a shaft in which the moment of inertia of the overhung section is smaller than that of the span between bearings; that is, $I_1 > I_2$. Basic equations for this system are found by essentially the same way as for Case 1. Note here that if $I_1 = I_2$, the frequency expression becomes the same as the simplified frequency expression for Case 1.

The accompanying *Design Example* demonstrates typical calculations for a shaft arrangement of this general type.

If two discs are attached to the shaft, and located as shown by Fig. 4, the critical speed can be calculated by the same method outlined previously for Case 1. In this instance,

$$f_n = \frac{187.7}{a} \times \left[\frac{3EI_1}{(a+lm)(W_{sa}+W) + (c+lm)W_1\left(\frac{c}{a}\right)^2} \right]^{1/2} \quad \ldots (7)$$

Large Overhung Moment of Inertia: Case 3 in Table 1 represents a shaft in which the moment of

Design Example

A vertically suspended shaft with a disc attached at the overhung end is shown in Fig. *A*. The shaft section between the bearings is hollow; OD = 3 21/32 in., ID = 1¼ in., and I_2 = 8.6 in.⁴ The overhung shaft section is solid; OD = 2½ in., I_1 = 1.91 in.⁴, and W_s = 111.3 lb. Shaft material is steel with $E = 30 \times 10^6$ psi. For the disc (turbine), weight is 70 lb, J_{om} = 13 lb-in.-sec², and $J_{em} = J_{om}/2$ = 6.5 lb-in.-sec.²

Determine the fundamental natural frequency of the shaft system.

Solution: Case 2 of Table 1 applies here. By definition, ratio m = 1.91/8.6 = 0.22. From the expression for equivalent shaft weight,

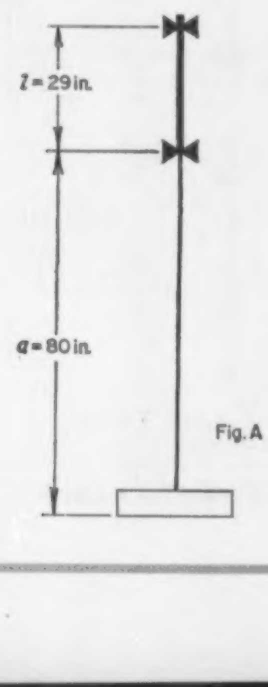


Fig. A

W_{sa} = 111.28 (0.242) = 26.93 lb. From the frequency expression then,

$$f_n = \frac{187.7}{80} \left\{ \frac{3(30)(10)^6(1.91)}{[80 + 29(0.22)](26.93 + 70)} \right\}^{1/2}$$

$$= 336.5 \text{ cpm}$$

Next, check the effect of gyroscopic action on the fundamental natural frequency, using Equation 2.

Since the concentrated load, $P = W_{sa} + W$, at the overhung end is known, static deflection δ_{max} and tangent angle ϕ_m can be readily calculated. From Table 1, the static deflection formula gives,

$$\delta_{max} = \frac{96.9(80)^2}{3(30)(10)^6(1.91)} [80 + 29(0.22)]$$

$$= 0.312 \text{ in.}$$

Tangent angle at the overhung end is

$$\phi_m = \frac{Pa(3a + 2lm)}{6EI}$$

which can be derived directly, using, for example, the area-moment method. Substituting,

$$\phi_m = \frac{96.93(80)}{6(30)(10)^6(1.91)} [3(80) + 2(29)(0.22)]$$

$$= 0.005 \text{ rad}$$

From Equation 3 then,

$$f_n = 187.7 \times \left\{ \frac{96.93(0.312)}{96.93(0.312)^2 - 386(13 - 6.5)[50(10)^{-4}]^2} \right\}^{1/2}$$

$$= 338.0 \text{ cpm}$$

Thus, in this case, gyroscopic action increases the fundamental natural frequency about 0.5 per cent.

inertia of the overhung section is larger than that of the span between bearings. In fact, for the shaft arrangement shown: $I_1 > I_0$ and $I_1 > I_2$. This rather unusual situation is frequently found in glassed agitator shafts where couplings cannot be applied in the usual way.

This shaft arrangement involves a much more complex distribution of moments of inertia than the previous two cases. To determine the maximum deflection produced by an arbitrary force, P, at the end of the shaft, it is convenient to use the Castigliano theorem. Thus, when the effect of shear is neglected, the result is the expression given in Table 1. The frequency expression is found, as before, by equating maximum kinetic and potential energies.

Here, the equivalent system must be based on three, rather than two, beams. If the bearing span weight is neglected, two equivalent weights, W_{ea} (overhang) and W_{eb} (intermediate section), must be calculated and added to the concentrated load at the end of the shaft. Expressions for these equivalents are also given in Table 1.

The frequency equation in Table 1 is also applicable to stepped shafts with one disc at the end, if span b is part of the overhang. Usually, intermediate section b is comparatively short and, for shafts with only one disc attached at the end, this equation reduces to

$$f_n = \frac{187.7}{a}\left(\frac{3EI_1}{Z_4}\right)^{1/2} \tag{8}$$

where

$$Z_4 = \left[a + lm\left(1 + \frac{b}{a}\right)^2 + 3bq\left(1 + \frac{b}{a}\right)\right][W_{ea} + W]$$

Corresponding equivalent weight W_{ea} becomes

$$W_{ea} = W_a \times \frac{Z_5}{420a\left[a + lm\left(1 + \frac{b}{a}\right)^2 + 3bq\left(1 + \frac{b}{a}\right)\right]^2} \quad \ldots (9)$$

where

$$Z_5 = (a + b)\left[140l^2m^2\left(1 + \frac{4b}{a}\right) + 210lbmq\left(4 + 11\frac{b}{a}\right) + 21lm(11a + 15b) + 630b^2q^2\left(2 + 3\frac{b}{a}\right)\right] + 21bq(39ab + 15b^2 + 33a^2) + 99a^3$$

For most agitating systems, this equation gives $W_{ea} = 0.25\ W_a$ to $0.28\ W_a$.

If span b is very short, the simplification can be carried further. Consider a shaft with two attached discs where span b is relatively short, Fig. 5. Fundamental natural frequency of vibration is

$$f_n = \frac{187.7}{a}\left(\frac{3EI_1}{Z_6}\right)^{1/2} \tag{10}$$

where

$$Z_6 = \left[a + lm\left(1 + \frac{b}{a}\right)^2 + 3bq\left(1 + \frac{b}{a}\right)\right] \times (W_{ea} + W) + \left[c + lm\left(1 + \frac{b}{c}\right)^2 + 3bq\left(1 + \frac{b}{c}\right) W_1\left(\frac{c}{a}\right)^2\right]$$

From Equation 10, it can be seen that the critical speed of the shaft is inverse to ratio $q = I_1/I_0$. Thus, if the moment of inertia of span b is small, the natural frequency will be low. To compare the simplified frequency expressions for Cases 1, 2, and 3 in Table 1, it is necessary to equate b and W_{eb} to zero. Thus, if $I_1 = I_2$ in Case 3, the frequency equation becomes the same as for a uniform cross-section shaft, Case 1. If $I_1 < I_2$ and $b = 0$ in Case 3, the frequency equation corresponds to Case 2.

If $I_0 = I_2$, which corresponds to $m = q$, and $b = 0$, the frequency equation in Case 3 gives the lowest fundamental natural frequency for this particular shaft arrangement.

Used in combination with the von Dunkerley approximation, the frequency equation for Case 3 also can be helpful in the analysis of suspended shafts with other load arrangements and different ratios of sectional moments of inertia. Therefore, in certain respects, this frequency equation is the general one. However, since the effect of shearing forces was disregarded, application of this equation is limited to shafts where ratios I_1/I_2 and I_0/I_2 do not substantially affect the continuity of the deflection curve of the deformed shaft.

There is another drawback to general use of this equation. In its present form, which applies to a shaft with three different sectional moments of inertia, it is already complex. Thus, if the sectional moments of inertia and bending moments vary in a more complicated manner, the evaluation of integrals for kinetic and potential energies becomes even more difficult. For such shafts, a graphical method is preferable.

Part 2 of this series covers the graphical method for determining natural frequency, and discusses the effect of support elasticity on calculated results.

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How to use

Servo Systems for Velocity Control

J. T. HANSEN
Project Engineer
Servocontrol Div.
Oilgear Co.
Waltham, Mass.

Dynamic performance, as well as accuracy of speed control, is an important requirement in many applications of hydraulic adjustable-speed drives. It's the dynamic performance that determines how quickly the drive corrects for load and input changes. This article, the third in a co-ordinated group of four, discusses the dynamic properties of electrohydraulic adjustable-speed drives.

FREQUENTLY, industrial applications require a drive that is continuously adjustable over a speed range of 100 to 1, or greater. Speed accuracy of 0.1 per cent is not an uncommon request.

This article details the use of electrohydraulics to meet these requirements for velocity control of hydraulic motors, and outlines a method for predicting dynamic performance of the system. A practical example illustrates the application of these techniques, and measured data verify the predictions. Previous articles discussed matching servovalve and load and the use of servovalves for force control.[1,2]

Basic Control Loops

Fig. 1 illustrates a basic electrohydraulic adjustable-speed drive. The mechanical load has already been reflected back through its gearing to the shaft of the hydraulic motor.[3] The driven load consists of inertia plus viscous friction. Load spring is considered absent since the output shaft is free to rotate. For initial simplicity, consider the viscous friction as negligible. Under these conditions, the position transfer function of the hydraulic motor-load combination is

$$\frac{\theta_1(s)}{Y(s)} = \frac{C_1}{d_m/2\pi} \Big/ s\left[\frac{J_1}{K_c\left(\frac{d_m}{2\pi}\right)^2}s^2 + \frac{J_1(K_l + C_2)}{\left(\frac{d_m}{2\pi}\right)^2}s + 1\right] \tag{1}$$

The stroking mechanism of the two-stage hydraulic-power source consists of a four-way servovalve driving a double-acting cylinder. The constant pressure supply and servovalve act as a single-stage hydraulic-power source. The mechanical load driven by the stroking cylinder is the mass plus viscous friction of the moving parts within the pump stroker.

[1]References are tabulated at end of article.

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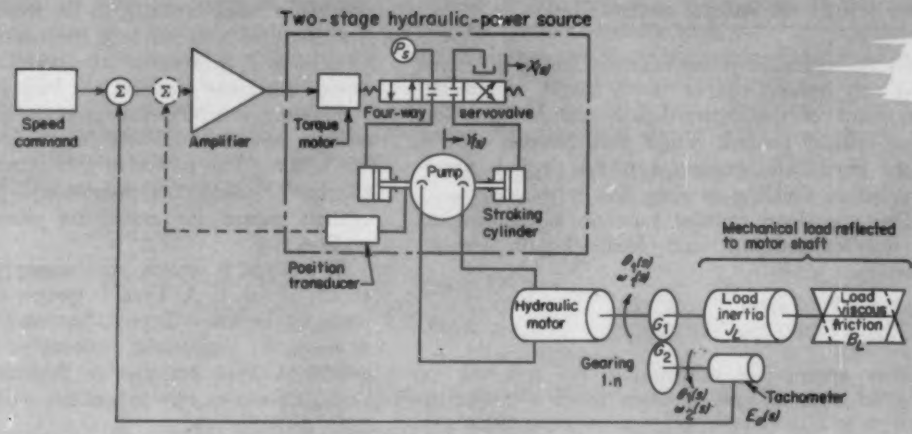
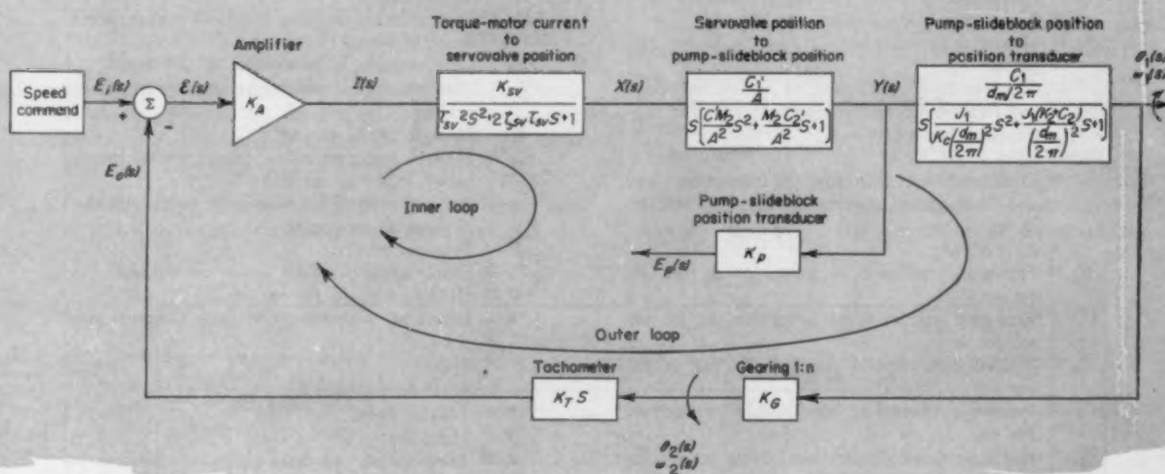


Fig. 1—Basic electrohydraulic adjustable-speed drive.

Fig. 2—Block diagram of drive shown in Fig. 1.



Considering leakage and viscous friction as negligible, the position transfer function of this translational mechanical assembly is[1]

$$\frac{Y(s)}{X(s)} = \frac{\dfrac{C_1'}{A}}{s\left(\dfrac{C'M_2}{A^2}s^2 + \dfrac{C_2'M_2}{A^2}s + 1\right)} \quad (2)$$

The tachometer output is a voltage proportional to the rate of change of input-shaft position. Thus, the transfer function for the tachometer is

$$\frac{E_o(s)}{\theta_2(s)} = K_T s \quad (3)$$

The block diagram, Fig. 2, represents the drive of Fig. 1. All transfer functions are shown. For simplicity, the amplifier response is considered to be flat; that is, only a steady-state gain constant term is present. Later it will be necessary to consider the effect of amplifier dynamics.

Four blocks in cascade form the forward path of the drive. The forward-path position transfer function is

$$\frac{\theta_1(s)}{\varepsilon(s)} = \frac{I(s)}{\varepsilon(s)} \times \frac{X(s)}{I(s)} \times \frac{Y(s)}{X(s)} \times \frac{\theta_1(s)}{Y(s)} \quad (4)$$

The feedback-path transfer function is

$$\frac{E_o(s)}{\theta_1(s)} = \frac{\theta_2(s)}{\theta_1(s)} \times \frac{E_o(s)}{\theta_2(s)} \quad (5)$$

After substitution of Equations 1, 2, and 3 into Equations 4 and 5, inspection reveals that the forward-path position transfer function contains the term, s^2, in the denominator. From basic servomechanism theory, an s^2 term in the denominator of an open-loop transfer function indicates a fundamental tendency for closed-loop instability. The position transducer sensing pump-slideblock position provides a means for closing an inner loop, for stability purposes, around the first stage of the

two-stage hydraulic-power source. Closing this inner loop will remove one of the s factors in the denominator of the forward-path transfer function. Since velocity control, rather than position control, is the immediate concern, a further look is necessary before deciding to close this inner loop.

The open-loop transfer function is the product of the forward-path and feedback-path transfer functions:

$$\frac{E_o(s)}{\epsilon(s)} = \frac{\theta_1(s)}{\epsilon(s)} \times \frac{E_o(s)}{\theta_1(s)} \tag{6}$$

After appropriate substitution, the resulting expression contains only a single factor s in the denominator. The factor, s, in the feedback expression has cancelled a factor s in the denominator of the forward-path expression. Had the inner loop been closed, this factor s would not be present at all.

A factor s in the denominator of an open-loop transfer function indicates the presence of integrating action. The power of this factor s reveals the number of integrators present and provides a convenient means for classifying closed-loop control systems.

In a Type 0 system, the factor, s, is not present at all, $s^0 = 1$. A Type 0 system contains no integrating action. Type 0 systems are regulators. A servo, by definition, contains at least one integrator. A Type 1 system is, therefore, a true servo since it contains one integrator, a factor $s^1 = s$ in

Nomenclature

A = Piston area of pump stroking cylinder, sq in.
a = Translational acceleration, in. per sec^2
B_L = Viscous drag coefficient of load, in.-lb per rad per sec
C = Compressibility coefficient of connecting lines and fluid under compression in pump and motor, cu in. per psi
= $K_e + V/\beta$
C' = Compressibility coefficient of connecting lines and fluid under compression in pump stroker, cu in. per psi
= $K_e + V/4\beta$
C_1 = Flow-gain coefficient of pump, cu in. per sec per in.
C_1' = Flow-gain coefficient of servovalve, cu in. per sec per in.
C_2 = Pressure coefficient of pump, cu in. per sec per psi
C_2' = Pressure coefficient of servovalve, cu in. per sec per psi
d_m = Hydraulic-motor displacement, cu in. per revolution
d/dt = Derivative with respect to time, sec^{-1}
d^2/dt^2 = Second derivative with respect to time, sec^{-2}
E_i = Input command signal, v
E_o = Tachometer output signal, v
E_p = Output signal of slideblock-position transducer, v
f = Frequency, cps
I = Torque-motor current, amp
J = Mass moment of inertia, lb-in.^{2} per in. per sec^2
J_1 = Total equivalent mass moment of inertia at hydraulic motor shaft (rotor inertia of hydraulic motor plus all load inertia reflected to hydraulic motor shaft), lb-in.^{2} per in. per sec^2
J_L = Mass moment of inertia of load, lb-in.^{2} per in. per sec^2
K = Loop gain constant, dimensionless
K_A = Amplifier gain constant, amp per v
K_c = Reciprocal of compressibility coefficient C, psi per cu in.
= β/V for variable-stroke pump, if connecting lines are rigid ($K_e = 0$)
= $4\beta/V$ for four-way servovalve, if connecting lines are rigid ($K_e = 0$)
K_e = Elasticity coefficient of connecting lines, cu in. per psi
K_G = Gain constant of gearing, dimensionless
= $1/n$
K_l = Leakage coefficient of hydraulic motor cu in. per sec per psi
K_p = Gain constant of pump slideblock-position transducer, v per in.
K_{sv} = Gain constant of servovalve, in. per amp
K_T = Gain constant of tachometer generator, v per rad per sec
M = Mass, lb per in. per sec^2
M_2 = Mass of load and piston (pump stroker moving parts), lb per in. per sec^2
n = Ratio of motor-shaft rotation to tachometer-shaft rotation, dimensionless
P = Pressure, psi
P_s = Supply pressure, pump stroker control, psi
Q = Fluid flow, cu in. per sec
s = Derivative with respect to time (Laplace notation)
= d/dt
= $j\omega$, where $j = \sqrt{-1}$
T = Torque, lb-in.
t = Time, sec
V = Total volume of fluid under compression including connecting lines and stroking cylinder or motor, cu in.
v = Translational velocity, in. per sec
X = Servovalve displacement from neutral, in.
Y = Pump-slideblock displacement from neutral, in.
Y' = Peak sinusoidal value of Y, in.
α = Angular acceleration, rad per sec^2
α_1 = Angular acceleration of hydraulic-motor shaft, rad per sec^2
β = Bulk modulus of fluid, psi
= 1.7×10^5, practical value for oil
ϵ = Error signal, v
ζ = Damping ratio, dimensionless
ζ_{sv} = Damping ratio of servovalve, dimensionless
θ_1 = Angular position of hydraulic-motor shaft, rad
θ_1' = Peak sinusoidal value of θ_1, rad
θ_2 = Angular position of tachometer shaft, rad
τ = Time constant, sec
τ_{sv} = Time constant of servovalve, sec
= Reciprocal of servovalve natural resonant frequency
ω = Angular velocity or frequency, rad per sec
= $2\pi f$
ω_n = Natural resonant frequency (angular), rad per sec
ω_1 = Angular velocity of hydraulic-motor shaft, rad per sec
ω_2 = Angular velocity of tachometer shaft, rad per sec

the denominator of its open-loop transfer function. A Type 1 system or servo is preferable to a regulator since the presence of integrating action means that, in steady state, the system will operate with essentially zero error. This arrangement results in significantly higher steady-state accuracy. Thus, electrohydraulic adjustable-speed drives employing tachometer feedback should operate with the inner loop left open.

Dynamic Performance

As Fig. 2 indicates, several portions of the control loop possess dynamic properties. These properties are important since, when taken together, they determine the over-all system dynamics.

Amplifier: Up to now, the amplifier transfer function has been considered to consist of a gain constant term only. This assumption may be valid for some amplifiers. More typically, however, amplifiers used to drive torque motors display output characteristics which can be approximated more closely by the transfer function, $K_A/(\tau s + 1)$. In some cases, the transfer function, $K_A/(\tau^2 s^2 + 2\zeta\tau s + 1)$, is more appropriate. In either case $\tau = 1/(2\pi f)$, where the value of f is about 25 cps. For the latter case, the damping ratio is about 0.8.

Servovalve: The block labeled *Torque-motor current to servovalve position* indicates that the dynamics of this portion of the system are characterized by the second-order term, $\tau_{sv}^2 s^2 + 2\zeta_{sv}\tau_{sv} s + 1$. The natural resonant frequency of this quadrantic is the reciprocal of the time constant, τ_{sv}. For servovalve capacities up to about 8 gpm at 1000 psi, this resonant frequency is approx 200 cps or above.

Pump Slideblock: Dynamics here are also characterized by a second-order term. Its natural resonant frequency is

$$\omega_n = 2A\sqrt{\frac{\beta}{VM_2}} \tag{7}$$

The order of magnitude for this pump-slideblock resonance is 100 cps.

Hydraulic Motor and Load: This combination also contributes a second-order term. The natural resonant frequency of the combination is

$$\omega_n = \frac{d_m}{2\pi}\sqrt{\frac{K_e}{J_1}} \tag{8}$$

For industrial applications, this resonance may range from a few cycles per second up to almost 100 cps, depending upon the inertia of the load and the volume of oil under compression. A value of 5 cps is typical.

The servovalve and slideblock resonances are typically one to two orders of magnitude (factors of 10) greater than the hydraulic motor-load resonance. Therefore, the second-order terms of the

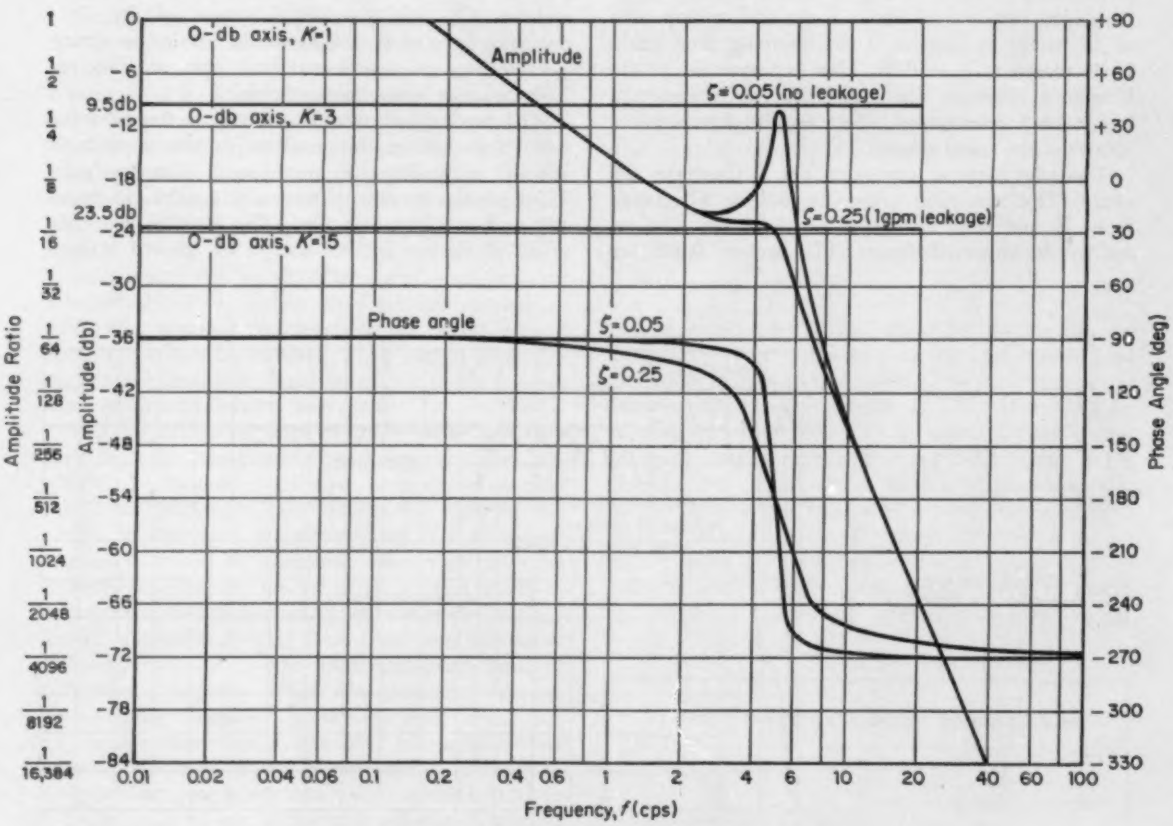


Fig. 3—Open-loop speed frequency response of a typical drive.

servovalve and slideblock can be neglected without introducing serious error.

Control Response: Frequently, dynamic response of the drive depends almost entirely upon the dynamic properties of the hydraulic motor-load combination. Amplifier dynamics may modify this slightly. The greater the motor-load resonance, the faster the speed control can respond to changes in load or input commands.

The open-loop frequency response, $E_o(s)/\epsilon(s)$, for an electrohydraulic adjustable-speed drive possessing a motor-load resonance of 5 cps is shown in Fig. 3. A typical order of magnitude for hydraulic-source parameter C_2 is 10^{-3} cu in. per sec per psi. The damping ratio can be calculated from

$$\zeta = \frac{J_1(K_l + C_2)}{2\left(\frac{d_m}{2\pi}\right)^2}\omega_n \tag{9}$$

With leakage considered negligible, a damping ratio of about $\zeta = 0.05$ results. Fig. 3 indicates that, for this damping ratio, the closed-loop speed-control system is limited to a frequency response of about 0.5 cps and a loop gain of 3 (approximately +10 db). Fig. 3 also indicates that a frequency response of about 5 cps and a loop gain of 15 would be possible if the damping ratio could be increased to $\zeta = 0.25$. This improvement of the frequency response, about one order of magnitude, has a very pronounced effect on the dynamic response of the speed control.

The step-response curves of Fig. 4 illustrate this effect. The rise time (time for output to change from 10 per cent to 90 per cent) of the step response is improved from 0.875 sec to 0.075 sec simply by increasing the motor-load damping ratio which, in turn, permits increasing loop gain K. On continuous web-type process applications, this improvement in the dynamic response of the system could make the difference between a drive that works satisfactorily and one that doesn't. There would be little difference in the steady-state speed accuracy of the two drives. However, one would respond to load and input command changes ten times faster than the other.

Damping-Ratio Control: How can the damping ratio be increased, and what is required to implement this system improvement?

Until now, internal leakage in the hydraulic motor has been ignored. Equation 9 shows that this leakage, K_l, has the same effect on the damping ratio as does the hydraulic-source parameter C_2. Increasing either K_l or C_2 increases the damping ratio. Experience indicates that the value of K_l is usually less than 50 per cent, and frequently 5 to 20 per cent, of the value of C_2. Thus, motor leakage usually produces a relatively insignificant effect on damping ratio.

What about purposely introducing leakage across the hydraulic motor to simulate motor leakage? The deliberate leakage can be produced easily by installing an orifice between the output-pressure ports of the two-stage hydraulic-power source. An across-port leakage of about 0.25 gpm at 1000 psi would produce a value of K_l of approximately 10^{-3} cu in. per sec per psi. This is the same order of magnitude as C_2. For the typical system of Fig. 3, a damping ratio of $\zeta = 0.25$ would require an across-port leakage of approximately 1 gpm at 1000 psi. This quantity is not unreasonable.

The mechanical viscous friction of the load has been neglected in this analysis. It also contributes toward increasing the motor-load damping ratio. Load viscous friction, however, is a nebulous quantity and is seldom specified. The possible beneficial effect of viscous friction should be ignored in con-

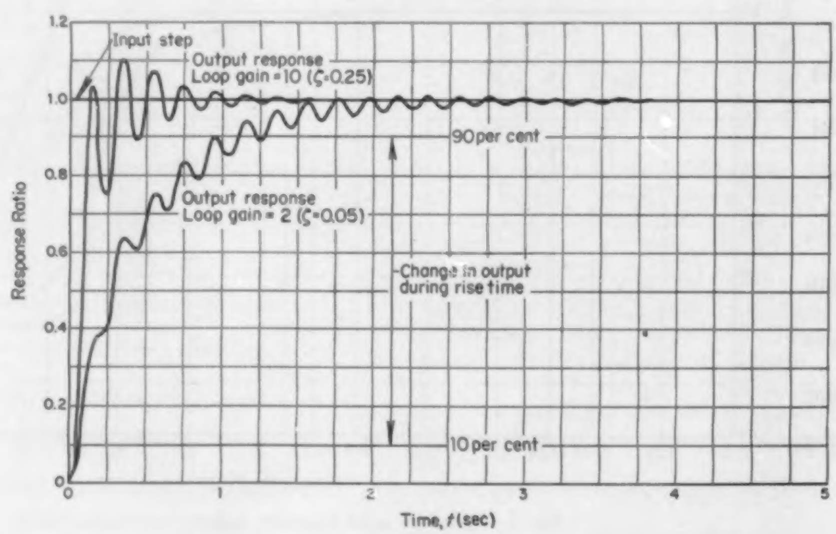


Fig. 4—Closed-loop speed step response of a typical drive.

trol-system design. Then, whatever it does contribute tends to improve the situation.

Other means for increasing the damping ratio include acceleration feedback or pressure feedback. Both of these methods require the addition of appropriate transducers to obtain electrical signals proportional to the parameters sensed.

System Accuracy

In all closed-loop control systems, any variation in the output of a forward-path element appears in the control-system output reduced in magnitude by a factor equal to loop gain K. Increasing the loop gain improves accuracy. Control-system stability places an upper limit on the permissible loop gain. Variations in the output of a feedback-path element appear in the control-system output without benefit of attenuation. Therefore, the accuracy of a closed-loop control system can be no better than the accuracy of its feedback-path elements. In the basic electrohydraulic adjustable-speed drive being considered, a tachometer generator is the feedback-path element.

For frequencies one order of magnitude or more below the hydraulic motor-load resonance, a good approximation of the open-loop transfer function is

$$\frac{E_o(s)}{\varepsilon(s)} = \frac{K}{s} \tag{10}$$

Since $E_o(s)$ is directly proportional to output speed, and s can be considered directly proportional to frequency, the ratio of output speed to error becomes infinite when the frequency goes to zero. Zero frequency represents steady-state conditions. The steady-state error must be zero to satisfy this requirement at finite output speeds. Thus, in the steady-state condition, the output speed must exactly agree with the speed being specified at the input.

In practice, zero steady-state speed error is never attained. However, values that are low enough to meet the accuracy requirements of many critical applications can be attained. Such factors as equipment resolution and signal-threshold levels prevent integrating out to exactly zero error.

The frequency response of the system is significant in terms of dynamic-speed accuracy. By definition, the frequency response of a device is that range of frequencies over which the ratio of the output to the input is constant within a given tolerance. In terms of accuracy, the system may be expected to respond, on an instantaneous basis, to an accuracy within the frequency-response conditions for all sinusoidal cycling rates from zero frequency (steady state) up to the upper-frequency limit of its dynamic response. Thus, the frequency-response improvement suggested previously from about 0.5 cps to approximately 5 cps, also means improved dynamic accuracy. A steady-state speed accuracy of 0.1 per cent over a continuously adjustable 100 to 1 speed range is not difficult to achieve. A typical maximum speed might be 1800 rpm, which means a steady-state speed accuracy of ± 1.8 rpm or better.

Practical Example

An electrohydraulic adjustable-speed drive is to be applied to a 10,000-lb testing machine. Speed range of the motor is to be 22 to 2200 rpm. Desired speed accuracy is ± 0.1 per cent. The mechanical load consists of inertia plus viscous friction.

The load inertia when reflected to the motor shaft is 37 lb-in.^{2} and the frictional losses are estimated to require a motor torque of 25 lb-in. The 10,000-lb capacity of the machine represents a torque requirement of 15 lb-in. at the motor shaft.

In addition, the drive is to be capable of oscillating the load sinusoidally at a frequency of 1 cps, through a total angular travel of 12 revolutions of the motor shaft.

Solution: The cyclic requirement can be expressed as:

$$\theta_1(t) = \theta_1' \sin \omega t \tag{11}$$

Successive differentiation yields expressions for velocity and acceleration:

$$\omega_1(t) = \frac{d}{dt}\,\theta_1(t) = \theta_1'\,\omega \cos \omega t \tag{12}$$

and

$$\alpha_1(t) = \frac{d^2}{dt^2}\,\theta_1(t) = -\,\theta_1'\,\omega^2 \sin \omega t \tag{13}$$

The motion-producing component of flow and the angular velocity are related by:

$$Q = \frac{d_m}{2\pi}\,\omega \tag{14}$$

Torque and angular acceleration are related by:

$$T = J\alpha \tag{15}$$

The total inertia that must be driven by the hydraulic motor is the sum of the load inertia plus the rotor inertia of the motor. The rotor inertia for two possible motor choices is 15.3 lb-in.^{2} (3-hp motor) and 74.3 lb-in.^{2} (8-hp motor). Comparison of motor inertia reveals that the 3-hp motor has a definite inertia advantage in this application. Use of the 3-hp motor results in a total inertia of 52.3 lb-in.^{2} Substitution into Equation 15 yields a torque of 201 lb-in. to create the peak acceleration of 1480 rad per sec.^{2} This torque requirement is about one order of magnitude greater than the torque

Table 1—Hydraulic-Motor Specifications

Normal pressure	1100 psi
Rated speed	1620 rpm
Displacement	0.682 cu in. per revolution
Mass moment of inertia	15.3 lb-in.^{2}

required to meet the output rating of the machine or to overcome the frictional losses.

Comparison of Equations 12 and 13 reveals that the peak torque during cyclic operation occurs when flow is zero. This results from the fundamental difference between a sine and cosine. Also, the peak flow occurs when the torque is zero.

The maximum theoretical torque developed by a hydraulic motor is

$$T = \frac{d_m}{2\pi} P \tag{16}$$

The 3-hp motor produces a stall torque of 114 lb-in. at 1100 psi and 95 per cent efficiency. This value is about 50 per cent of the required peak torque. The 8-hp motor would develop 330 lb-in. under these same conditions. However, the peak torque required for acceleration of the inertia would increase to 425 lb-in. due to the increase in rotor inertia. A better choice would be the use of two 3-hp motors arranged in parallel to make their torque outputs additive. The peak torque required would not exceed 300 lb-in. (inertia, 260 lb-in.; friction, 25 lb-in.; output 15 lb-in.). At 1100 psi, the two 3-hp units develop 228 lb-in. Their stall torque could be increased to 300 lb-in. merely by increasing the pressure to 1450 psi. The design of this electrohydraulic adjustable speed drive will be based upon the use of two 3-hp motors to meet the cyclic operation torque requirements. Specifications for this motor are given in Table 1.

The peak-velocity requirement of 236 rad per sec (from Equation 12) corresponds to 2260 rpm. At this speed, Equation 14 indicates a peak-flow requirement of 3080 cu in. per min.

A reasonable choice for the hydraulic source is an 8-hp electrohydraulic variable-stroke pump rated at 3190 cu in. per min at 1100 psi when driven at 1750 rpm. This pump matches the flow requirements. A slight increase of its high-pressure relief-valves setting provides the 1450-psi peak pressure. This amount of overpressuring of the pump and motors is not serious, particularly since it is not a continuous requirement. The specifications for this pump are given in Table 2.

Table 2—Hydraulic-Pump Specifications

Normal pressure	1100 psi
Displacement	1.92 cu in. per revolution
Stroke	±0.214 in.
Control-piston diameter	3.188 in.

Table 3—Actual Performance

Maximum speed	2200 rpm, cw or ccw
Minimum speed	Less than 10 rpm, cw or ccw
Speed range	Better than 200 to 1
Accuracy	±1 rpm (±0.05 per cent)
Repeatability	±1 rpm or better
Resolution	Better than 0.5 rpm

Hydraulic motor-load resonance can be determined by use of Equation 8. The total oil under compression is 27.8 cu in. (28.4 cu in. piping; 22.4 cu in. inside pump; 4.8 cu in. inside motors—all divided by 2 since only one line is pressurized at a time).

$$\omega_n = \frac{2(0.682)}{2\pi} \sqrt{\frac{1.7 \times 10^5/27.8}{67.6/386}}$$

$$= 40.7 \text{ rad per sec}$$

$$= 6.5 \text{ cps}$$

This resonance value of 6.5 cps is not significantly different from the 5 cps value illustrated in Fig. 3. Thus, Fig. 3 can be considered as representing the frequency response of this speed-control application.

The 1-cps cycling requirement is well within the dynamic response of this hydraulic motor-load combination. Thus, the cyclic requirements will be met if the peak flow of 3080 cu in. per min and the peak torque of 300 lb-in. are available. Actually, the load could be cycled up to about 6.5 cps as long as the flow and torque requirements are available.

During cyclic operation, the displacement of the pump-stroker cylinder can be expressed as

$$Y(t) = Y' \sin \omega t \tag{17}$$

Successive differentiation yields expressions for velocity and acceleration:

$$v(t) = \frac{d}{dt} Y(t)$$

$$= Y' \omega \cos \omega t \tag{18}$$

and

$$a(t) = \frac{d^2}{dt^2} Y(t)$$

$$= -Y' \omega^2 \sin \omega t \tag{19}$$

The relationship between flow and velocity is $Q = Av$, and between pressure and acceleration, $P = Ma/A$

By following a procedure similar to that outlined for selecting the hydraulic motors and pump, the flow and pressure requirements for the pump-stroker mechanism can be calculated. From these requirements, the size of the four-way servovalve can be determined.

Actual Performance

Table 3 indicates the actual performance obtained from the drive described in the *Practical Example*.

The input-command device is a 25-turn potentiometer. A servovalve rated at 6.5 gpm at 1000 psi drives the stroking cylinders from a control pressure of 200 psi. All electrical equipment operates from the 115-v 60 cycle supply. The amplifier is free from drift since it is an ac-carrier type with the conversion to dc accomplished through force rectification at the armature of the torque motor.

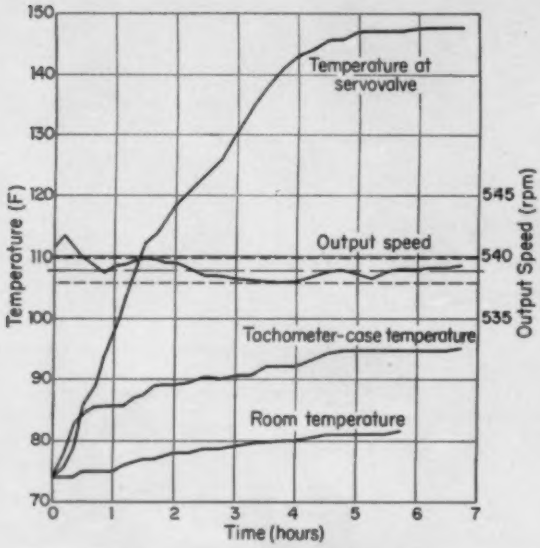


Fig. 5—Measured performance of the drive selected in the *Practical Example*.

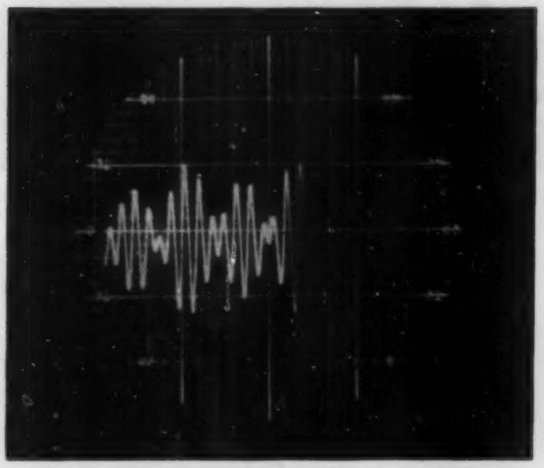


Fig. 6—Error voltage at the amplifier input. Time scale = 0.020 sec per division.

The arrangement of the electrical circuit minimizes speed variations due to changes in line voltage. The line voltage was purposely varied ±15 per cent. No change in output speed could be detected on a digital tachometer sensing twice output speed, 30 times per minute.

Accuracy: Output speed versus time is shown in Fig. 5. During the almost seven hours of operation, the speed accuracy is within ±2 rpm. Allowing a half-hour warm up period the speed accuracy is ±1 rpm. Performance at other speeds and in the opposite direction compares favorably with the performance illustrated.

Dynamic Response: A rough check of the hydraulic motor-load resonance can be obtained from the oscillogram, Fig. 6, of error voltage at the input to the amplifier. Loop gain was increased until sustained loop oscillation occurred. The waveform is that of the 60-cps line frequency, suppressed-carrier modulated by the oscillating frequency of the control loop. From the oscillogram, the period of the modulation frequency is about 133 millisec. This corresponds to a frequency of 7.5 cps (f = 1/period, sec), and can be considered approximately equal to the hydraulic motor-load resonant frequency. This compares favorably with the predicted motor-load resonance of 6.5 cps. Such a system would ordinarily be operated at a loop gain of 15 to 25.

To check the effect of small load changes on speed accuracy, the drive was subjected to step changes in load of approximately 5 per cent of rating. The initial display of output speed after the application of a step load change indicated a speed deviation. By the second display, the digital tachometer indicated that the output speed had returned to its original value.

The cyclic requirement was checked by operating the drive in the open-loop configuration from a sine-wave generator. The 1 cps, 12 revolution peak-to-peak sinusoidal motion of the motor shaft was obtained with ease.

Temperature Effects: Changes in temperature at the servovalve, Fig. 5, have very little effect upon output speed, since closed-loop control reduces the effect of variations in forward-path elements by a factor equal to the loop gain (15 to 25).

After the first half hour of operation, the rate at which the tachometer-case temperature increases is about equal to the rate at which room temperature increases. It can be concluded that temperature rise of the tachometer due to its internal electrical losses levels out in approximately a half hour after the 110-v power is applied to the tachometer-excitation winding. Although the tachometer is temperature compensated, the compensation is not perfect. Thus, the output of the tachometer does vary a small amount with changes in temperature. Since variations in the output of a feedback-path element appear in the output of the control loop without benefit of attenuation, it is imperative that drift in the tachometer output be held to a minimum, if high-accuracy speed control is desired. If the tachometer excitation is permanently energized, or turned on at least a half hour before the drive is operated, speed changes due to tachometer warm up can be avoided. Holding the ambient temperature of the tachometer at a constant value minimizes drift due to room temperature variations.

REFERENCES

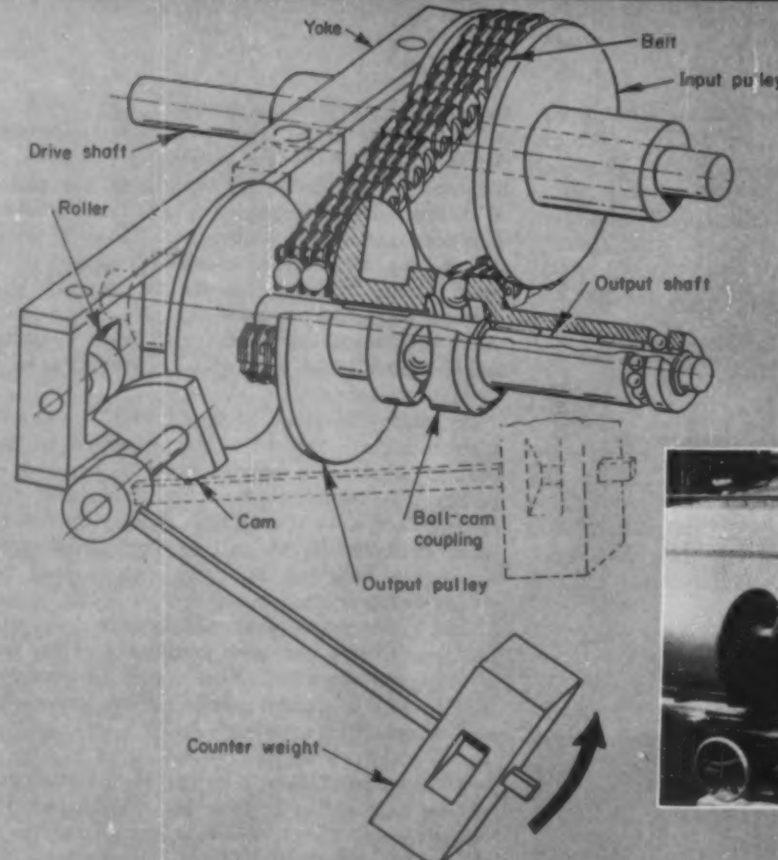
This article is the third in a co-ordinated group on servosystems. Previous articles, and the issues of MACHINE DESIGN in which they appeared are:

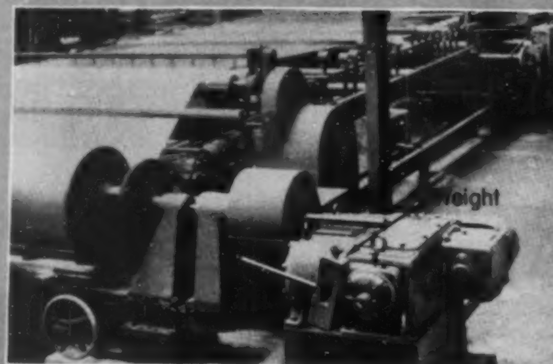
1. "Matching Servovalve and Load," by R. J. Procaccino, July 6, 1961.
2. "Servovalves for Force Control," by R. J. Procaccino, October 12, 1961.

The fourth and concluding article in this group will discuss use of servo systems for position control.

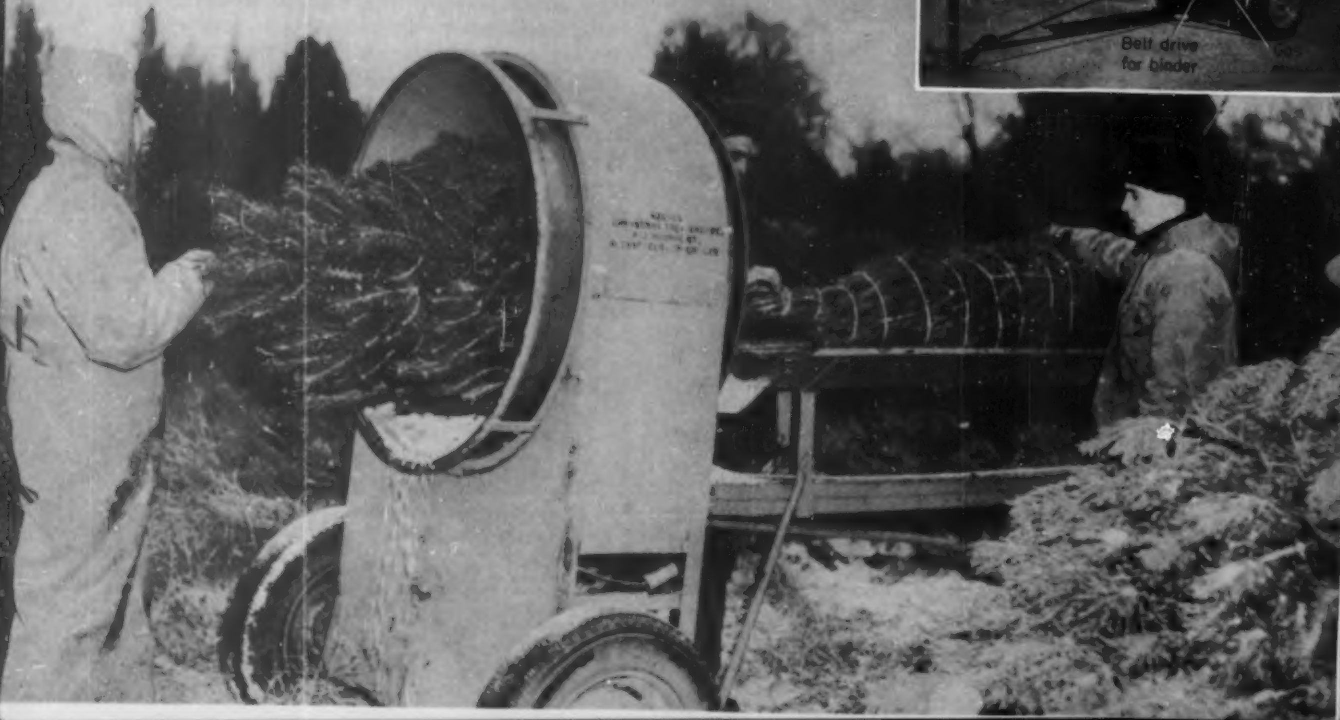
Another MACHINE DESIGN reference mentioned in the current article is:

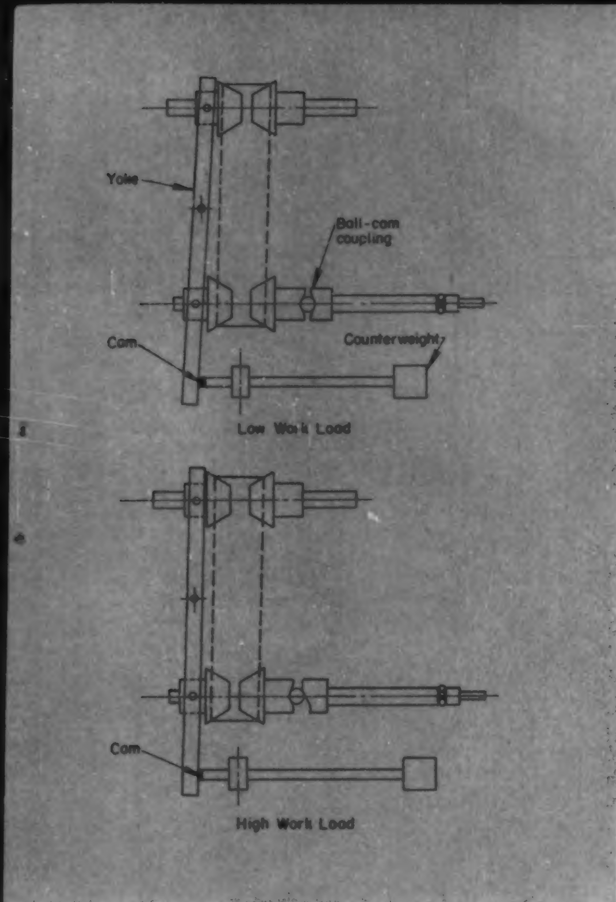
3. "Dynamic Properties of Hydraulic Motors," by J. T. Hansen, January 19, 1961.


Yoke
Belt
Input pulley
Drive shaft
Roller
Output shaft
Cam
Ball-cam coupling
Output pulley
Counter weight




Dragline
Belt drive for binder





Automatic Split-Pulley Transmission

Self-adjusting transmission changes ratio with change in driven-machine load. Increased torque on the output shaft is converted to an axial force by the ball-cam coupling. Lever action of the yoke permits variable-pitch transmission pulleys to adjust in response to this axial force. Ratio compensation can be modified by repositioning yoke counterweight. Transmission was designed for a winding machine by PIV Antrieb Werner Reimers KG, Bad Homburg vdH, Germany.

Christmas Tree Bundler

Production-line bundler for Christmas trees uses a funnel-shaped compactor with a rotating twine binder. Trees are fed trunk-first from the rear through the funnel. Dragline cable and binder twine are fastened to the tree base. The dragline pulls the tree through the funnel as the binder winds the twine around it. Spacing of twine ties can be varied to suit the user's needs, and funnel inserts with openings down to 12 in. diam accommodate smaller trees. Standard wrapper handles trees up to 12 ft long. The Christmas Tree Wrapper was developed and patented by J. B. Saxton of Saxton Associates, Blissfield, Mich. It's powered by a 3-hp, 4-cycle Lauson gasoline engine built by Tecumseh Products Co., Tecumseh, Mich. A special air breather protects the engine from needles and debris.

Rolling Steam Plant

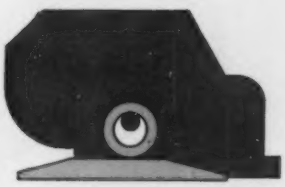
Steam ground unit for starting jet engines uses flash evaporator to build up a steam head in 5 seconds. Pressure and temperature of the steam are such that it can be used with existing low-pressure air starters. The unit is mounted on a long-base land cruiser. It carries enough fuel and water for up to 30 starts. The flash evaporator delivers steam at 160 C at the rate of 1.2 lb per sec. Fuel is consumed at the rate of 0.12 lb per second. The rolling steam plant is produced by Associated Electrical Industries Ltd., Aircraft Equipment Group, Coventry, England.

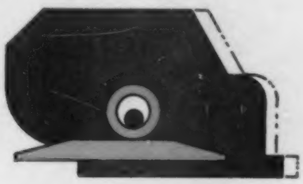
Stomping Dragline

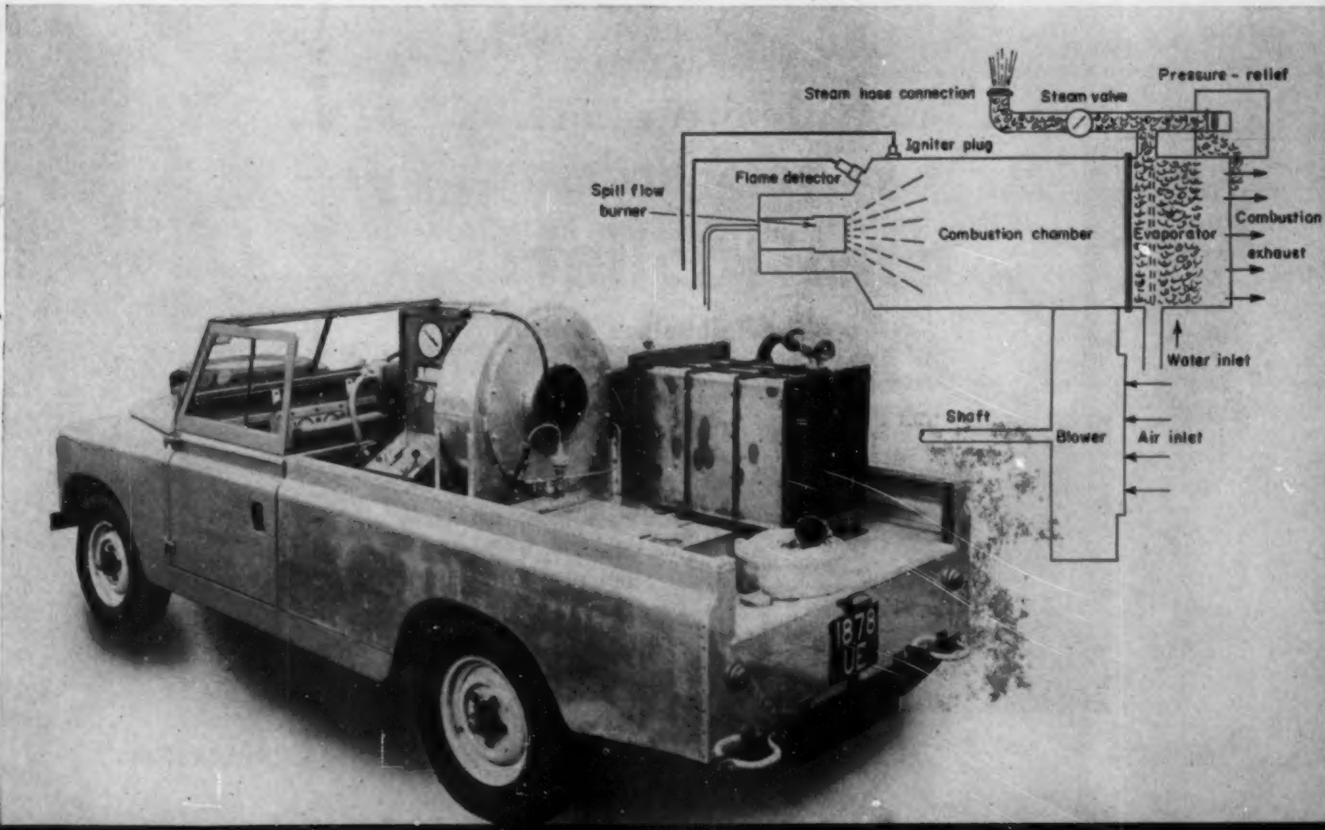
Massive feet take $7\frac{1}{2}$-ft strides to move a giant dragline excavator around a work site. They're operated by heavy eccentrics, each driven by two 225-hp motors. The walking crane is maneuvered by one man from either of two cabs flanking the boom. A complete control system for the dragline operation is included on the console in each cab.

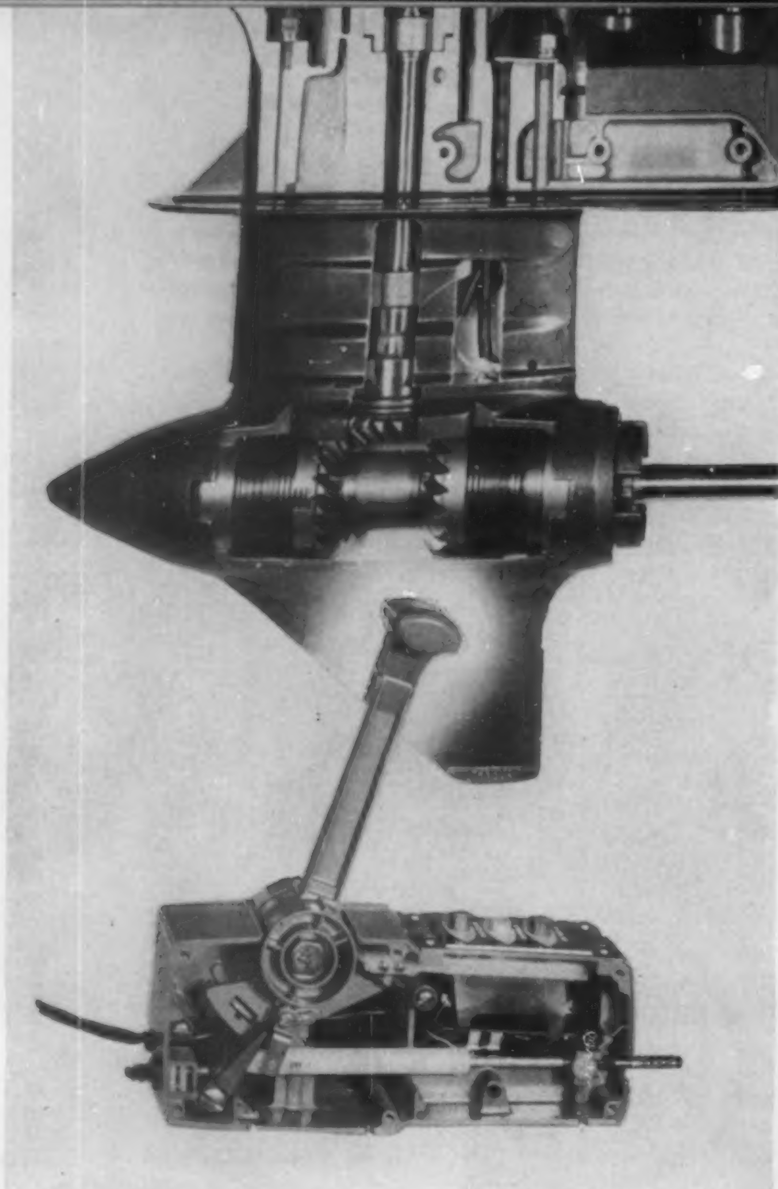
Machinery in the excavator includes 16 motors—8 rated at 300 hp each and the rest 225 hp each. The larger motors are divided between hoisting and dragging operations, while the smaller operate walking and swinging mechanisms.

Base diameter of the excavator is 55 ft. Roller circle diameter is 48 ft. The base gives a footing of 2380 square ft for the 75,000-lb machine. Bucket for the dragline, believed to be the largest in the world, has a capacity of 60 tons. Dragline excavator, RapieR W1800 was developed by Ransomes and Rapier, Ltd., Ipswich, U. K.



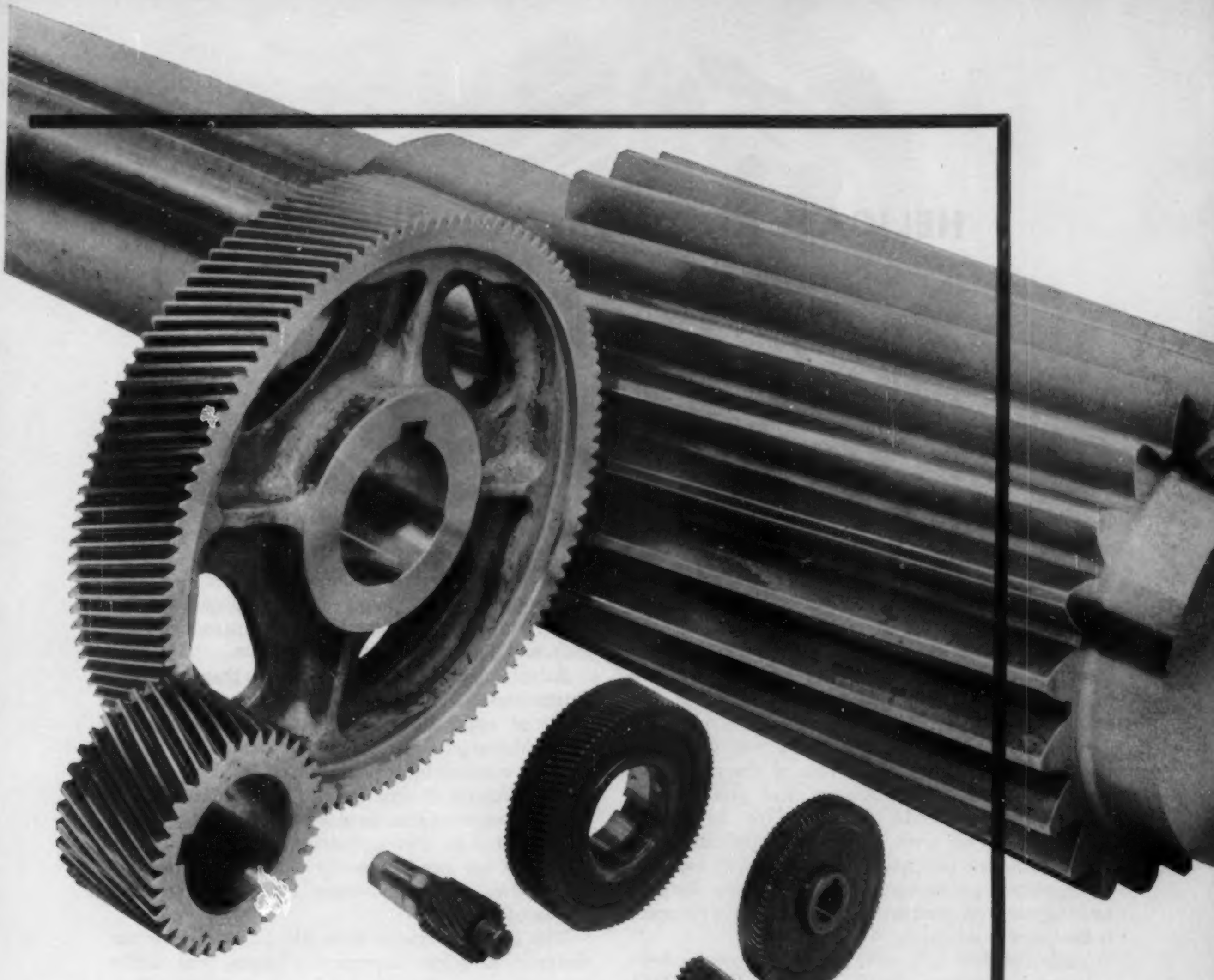






Pushbutton Shifting

Selection of forward or reverse is made by pushbutton in a new high-powered outboard motor. The button energizes an electromagnetic coil which causes a clutch spring to tighten on a hub splined to the propeller shaft. Forward and reverse bevel gears are provided with separate coil clutches. Shifting can be made directly from forward to reverse without going through neutral. The transmission design is by Evinrude Motors Div., Outboard Marine Corp., Milwaukee, Wisconsin.



How to predict the strength capacity of

Helical and Herringbone Gears

. . . a detailed design guide based on the new tooth-strength formula developed by AGMA's Gear Rating Committee

E. J. WELLAUER
Director, Research and Development
The Falk Corp.
Milwaukee, Wis.

HELICAL AND HERRINGBONE GEARS

LOADS that helical gears can transmit are normally limited by the pitting resistance of the tooth-profile surfaces. Gear strength becomes critical when materials of high hardnesses are used and for applications subject to high overloads. Both pitting resistance and tooth strength must be checked in design. Only tooth strength is discussed in this article.

A useful tooth-strength formula was developed by the Gear Rating Committee of the American Gear Manufacturers Association and published in tentative form, AGMA 225.01.[1] This formula is applicable to all types, sizes, and applications of gears. Sufficient information is provided to evaluate all important parameters and to allow the designer to integrate and compare his experiences with spur, helical, and bevel gears.

Technical data of a more specific nature for helical and herringbone gearing are found in AGMA Tentative Standard 221.02.[2] The primary purpose of this standard is to enable the designer to select the appropriate values of the salient parameters for his specialized application. Gear-tooth strength is significantly affected by small variations in accuracy and mounting rigidity. Simplification through compromise for a wide range of design uses sometimes can be technically undesirable or costly. Simplified design formulas for specialized application are feasible.

The designer is cautioned that a difference exists between actual capacity, rated capacity, and estimated capacity.

Actual capacity of a gear set is the load which can be transmitted by each individual set dependent upon its specific accuracy, mounting conditions, speed, materials, load characteristics, etc. Actual capacity is best determined by laboratory tests and field experience. All sets vary in actual capacity; an analysis of the statistical performance is necessary to indicate the conditions required to obtain the proper factor of safety for an application. This procedure is widely practiced for automotive, aircraft, and high-volume production gears.

Rated capacity of a gear set is that normally determined for minimum or average data, conditions, or applications. For example, the American Gear Manufacturers Association's standards pertinent to commercially produced enclosed gear units are particularly drafted for the high-accuracy gearing and precision-machined bearing bores and housings used for these products. These individual standards are not necessarily applicable to certain automotive, aircraft, machine tool, or other types of geared drives.

This article contains data which will enable the designer to select appropriate factors and derive his own rating formula for his specialized application.

Estimated capacity of a gear set is that determined either by the best available or the most rational procedures. Such estimates are determined either with formulas based upon empirical information or derived from a rigorous rationalization of theoretical principles. Empirical formulas offer little latitude for extension beyond the immediate boundaries between which the data were secured. Such formulas are usefully employed for preliminary determinations or selections.

More rational formulas, particularly when supported by rigorous technical derivations and with proper experimental or field verification, yield more precise estimates of capacity.

The designer can use the data in this article to develop formulas to estimate the strength capacity of helical or herringbone gear teeth to any degree of sophistication required for research, failure analysis, and design purposes.

[1]References are tabulated at end of article.

Fundamental Strength Formula

The cantilever-plate theory for determining the bending strength of gear teeth reported by Seireg and Wellauer[3] is an improvement over the older Lewis formulas which considered the tooth as a cantilever beam. A simplified derivation of the fundamental strength formula is given in References 4 and 5.

Bending-Stress Formula: The basic equation for the bending stress in a gear tooth is

$$s_t = \frac{W_t K_o}{K_v}\left(\frac{P_d}{F}\right)\left(\frac{K_s K_m}{J}\right) \tag{1}$$

Load

Tooth Size

Stress Distribution

The relation of calculated stress to allowable stress is

$$s_t \leq \frac{s_{at} K_L}{K_T K_R} \tag{2}$$

Allowable Working Stress

Power Formula: Power capacity of a gear set can be calculated as:

$$P_{at} = \frac{n_P d K_v}{126{,}000 K_o}\left(\frac{F}{K_m}\right)\left(\frac{J}{K_s P_d}\right)\left(\frac{s_{at} K_L}{K_R K_T}\right) \tag{3}$$

Equations 1 to 3 include all the known and measurable factors which affect helical-tooth strength. By becoming familiar with the information required to evaluate each factor, the designer will be in a position to ascertain those of significance for his purposes. References 4 and 5 present detailed suggestions.

Nomenclature

C_e = Force-error coefficient
C_h = Helical factor
d = Operating pitch diameter of pinion, in.
e = Alignment error, in. per in.
F = Net face width, in.
F_m = Face width factor in Fig. 5
h = Tooth height, in.
J = Geometry factor
K_f = Stress-correction factor
K_L = Life factor
K_m = Load-distribution factor
K_o = Overload factor
K_p = Stress-correction factor adjusted for notch sensitivity
K_R = Factor of safety
K_s = Size factor
K_T = Temperature factor
K_v = Dynamic factor
L = Total length of oblique lines of contact at worst condition (usually taken equal to the minimum length of the lines of contact), in.
m_N = Load-sharing ratio
n_P = Pinion speed, rpm
P_{at} = Allowable power of gear set, hp
P_d = Transverse diametral pitch
P_{nd} = Normal diametral pitch
p_b = Base pitch, normal to involute, in.
p_N = Normal base pitch, in.
q = Size and material stress-correction factor
r = Actual tooth-fillet radius, in.
s_{at} = Allowable tensile stress for material and heat treatment, psi
s_{ay} = Allowable yield stress, psi
s_t = Calculated tensile stress at root of tooth, psi
W_t = Transmitted tangential load at operating pitch diameter, lb
Y_s = Helical tooth-form factor
Z = Length of the line of action in the plane of rotation, in.
ϕ_n = Normal pressure angle, deg
ψ = Helix angle, deg

Design Factors

Some of the more significant details useful for practical design are presented in this section. The following factors apply to both single-helical and double-helical (and herringbone) types of gearing. For double-helical gearing the value of F is equal to the sum of the net widths of each helix.

Load

Transmitted tangential load W_t . . .

is determined from the power delivered by the gear set. This is not always easily determined from wattmeter readings or power-requirement calculations; sometimes instantaneous torque-meter readings are necessary. Typical readings so obtained for several types of gear loads are shown in Fig. 1. Nonuniform loads must be further studied in regard to the peak loads and their duration as well as the magnitude and number of cycles of intermediate loads.

When a few peak loads are encountered, the yield strength is sometimes the governing stress. Normally, the endurance limit is the major consideration. It is usual to designate a nominal load and compensate for peak loads. To some extent the duration of peak loads can be accounted for by means of overload factor K_o or a service factor.

Overload factor K_o . . .

measures the characteristics of both the driving and driven apparatus in terms of peak loads, inertia loading, acceleration forces, and other dynamic conditions. Typical overload factors and examples of drive combinations are shown in Table 1.

In a specialized field the designer can replace overload factor K_o by a service factor. Beside including the K_o evaluation, the service factor also can compensate for estimated service life, required reliability, or other conditions peculiar to the application. When a service factor is used, both K_R and $K_L = 1$. Service factors are widely used in the rating practices of AGMA.[6] Some typical values of

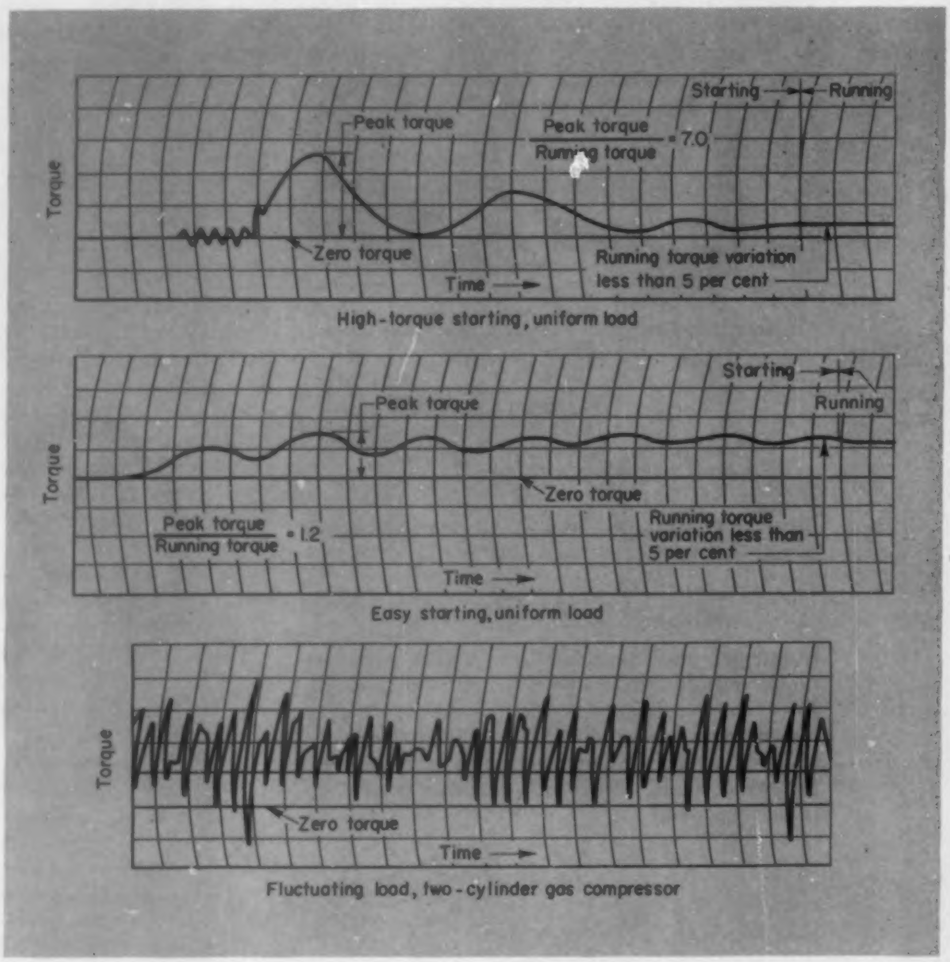


Fig. 1—Typical examples of torque variations in industrial gear drives.

service factors to use as a guide are shown in Table 2.

Beside load variations, additional force disturbances are developed between meshing gear teeth by the velocity effects of the connected rotating mechanism. These dynamic load increments are measured by the next factor.

Dynamic factor K_v . . .

can sometimes be taken as 1.0 when high-precision gears are used in a system having light masses, high elastic flexibility, or low speeds.

Fig. 2 shows the typical range within which K_v normally varies. When milling cutters are used to cut teeth or inaccurate teeth are otherwise developed, lower dynamic factors are used. In these cases pitch-line velocity in excess of 1500-2000 fpm is likely to cause the gears to be self-destructive.

Table 1—Overload Factors K_o

Character of Power Source	Character of Load on Driven Machine: Uniform	Moderate Shock	Heavy Shock
	Centrifugal blower, pure liquid agitator, belt conveyor (uniform feed)	Lobe - type blower, liquid and solid agitator, belt conveyor (nonuniform feed)	Ore crusher, single - cylinder compressor, reciprocating conveyor
Uniform Electric-motor, turbine	1.00	1.25	2.00
Light Shock Multicylinder internal-combustion engine	1.25	1.50	2.25
Medium Shock Single-cylinder internal-combustion engine	1.50	1.75	2.50

Tooth Size

Transverse diametral pitch P_d and face width F . . .

are the factors associated with tooth size. The designer is cautioned that the strength capacity is not directly proportional to these terms. The pitch governing tooth strength is actually the normal diametral pitch which varies in relation to the transverse diametral pitch: $P_{nd} = P_d/\cos\psi$. This correction is made in geometry factor J.

Likewise, face width F is not a direct index of strength capacity since the capacity is determined by load and stress distribution across the face.

Stress Distribution

Size factor K_s . . .

enters the calculations because size of components

Table 2—Service Factors Electric-Motor Drives*

Application	10-Hour Service†	24-Hour Service
Agitators		
Pure liquids	1.00	1.25
Liquids & solids	1.25	1.50
Liquids, variable density	1.25	1.50
Blowers		
Centrifugal	1.00	1.25
Lobe	1.25	1.50
Vane	1.00	1.25
Compressors		
Centrifugal	1.00	1.25
Lobe, rotary	1.25	1.50
Reciprocating:		
Single cylinder	1.75	2.00
Multicylinder	1.25	1.50
Conveyors		
Uniformly loaded or fed:		
Screw	1.00	1.25
Heavy-duty or not uniformly fed:		
Live roll	§	§
Reciprocating or shaker	1.75	2.00
Crushers		
Ore or stone	1.75	2.00
Elevators		
Bucket, uniform load	1.00	1.25
Bucket, heavy load	1.25	1.50
Man lifts	§	§
Fans		
Centrifugal	1.00	1.25
Cooling tower	§	§
Induced draft	1.25	1.50
Large industrial	1.25	1.50
Light (small diameter)	1.00	1.25
Machine Tools		
Auxiliary drives	1.00	1.25
Main drives	1.25	1.50
Punch press (geared)	1.75	2.00
Mills		
Rotary ball, dryers, coolers, cement kilns, pebble, rod	—	1.50
Kiln	1.25	1.50
Tumbling barrels	1.75	2.00
Pumps		
Centrifugal	1.00	1.25
Proportioning	1.25	1.50
Reciprocating		
Single-act., 3 or more cyl.	1.25	1.50
Double-act., 2 or more cyl.	1.25	1.50
Single-act., 1 or 2 cyl.	§	§
Double-act., single cyl.	§	§
Rotary: Gear, lobe, vane	1.00	1.25

*For multicylinder engines use a service factor 0.25 higher than that shown in the table. Single-cylinder engine-driven applications require individual study. Service factors usually will be higher than multicylinder engines. These service factors are based on the assumption that the system is free from serious vibrations.

†For intermittent duty (3 hr per day) use a service factor 0.25 lower than that shown in the table. For occasional duty (½ hr per day) consider individually. High-starting or peak transient loads must be individually considered if they exceed 200 per cent of the nominal load.

§Specific load studies are required for each application.

seems to influence allowable stresses. For larger gears there are greater statistical possibilities for the occurrence of weak areas and differences in stress and load gradients. Size factor $K_s = 1$ can be used satisfactorily for most heat-treated helical gears. An exception is case-hardened gears, Fig. 3. Data in Fig. 3 allow for a probable lower core hardness and the lesser strengthening effect caused by the surface compressive stresses developed within the case as the pitch becomes coarser.

Load-distribution factor K_m . . .

is the ratio of the maximum load intensity along the face width to the nominal load intensity based upon uniform distribution. Variations in load distribution can be caused by:

1. Cutting errors
2. Errors in rotating axis in mounting due to bore tolerances
3. Internal bearing clearances
4. Accuracy of the parallelism of shafts carrying each gear
5. Blank runout
6. Tooth stiffness
7. Blank stiffness
8. Shaft stiffness
9. Housing stiffness
10. Elastic bearing deflections
11. Hertz profile contact deflections
12. Thermal distortions
13. Uneven load distribution between the helices of double helical gears due to external thrust

Example 1—Strength Rating

As accurately as possible, determine horsepower rating, with respect to strength, of a helical pinion operating at n_P = 1800 rpm. The desired life is over 10^8 cycles. Gear data are as follows:

Transverse diametral pitch P_d = 10.61. Normal diametral pitch P_{nd} = 13.87. Face width F = 1.500 in. Pinion teeth N_P = 19. Gear teeth N_G = 80. Gear ratio m_G = 4.21. Helix angle ψ = 40 deg. Normal pressure angle ϕ_n = 22 deg. Operating pinion pitch diameter d = 1.800 in. Pinion outside diameter d_o = 1.993 in. Pinion base diameter d_b = 1.592 in. Gear operating pitch diameter D = 7.577 in. Gear outside diameter D_o = 7.675 in. Gear base diameter D_b = 6.703 in. Hardness of pinion = 335 Bhn min.

In this application, the misalignment that is not a function of load is 0.0005 in. per in. of gear face. For a 1000-lb tangential load, the misalignment due to transmitted load is 0.0002 in. per in. of face.

The following factors are considered when obtaining the total lead error of a gear set:

Not a function of load
1. Machining errors
2. Bearing clearances

A function of load
3. Elastic shaft deflection
4. Bearing deformation
5. Housing deformation

Solution: Find factors required for, and solve, Equation 3 for P_{at}. The steps are as follows:

1. Determine allowable stress s_{at}. The minimum pinion hardness is 335 Bhn. From curve 2 of Fig. 11, s_{at} = 38,800 psi.

2. Determine geometry factor J. From dimensions obtained from a gear-tooth layout, the geometry factor for the 19-tooth pinion is calculated to be J = 0.390.

3. Determine dynamic factor K_v. For commercial helical gears, the dynamic factor is obtained from curve 2 of Fig. 2. The pitch-line velocity is 850 fpm. K_v = 0.850.

4. Determine overload factor K_o. The overload factor is to be determined by the application for the strength horsepower rating. K_o = 1.0.

5. Determine size factor K_s. Let K_s = 1.0.

6. Determine factor of safety K_R. This design will be based on fewer than 1 per cent failures. From Table 4, K_R = 1.00.

7. Determine life factor K_L. From Fig. 13, K_L = 1.0; required life = 10^8 cycles.

8. Determine temperature factor K_T. Operating temperature of the gear box should not exceed 250 F. K_T = 1.0.

9. Determine the horsepower capacity in terms of load-distribution factor K_m. Solving for each group of terms in Equation 3:

$$\frac{n_P d K_v}{126{,}000 K_o} = \frac{1800(1.800)(0.850)}{126{,}000(1.0)} = 0.0219$$

$$\frac{F}{K_m} = \frac{1.500}{K_m}$$

$$\frac{J}{P_d K_s} = \frac{0.390}{10.61(1.0)} = 0.0368$$

$$\frac{s_{at} K_L}{K_R K_T} = \frac{38{,}800(1.0)}{1.0(1.0)} = 38{,}800$$

Finally,

$$P_{at} = \frac{0.0219(1.500)(0.0368)(38{,}800)}{K_m}$$

Standard relation of power to tangential load is

$$W_t = \frac{126{,}000 P_{at}}{n_p d}$$

Then,

$$W_t = \frac{1815}{K_m}$$

10. Determine line-of-action length Z and base pitch p_b

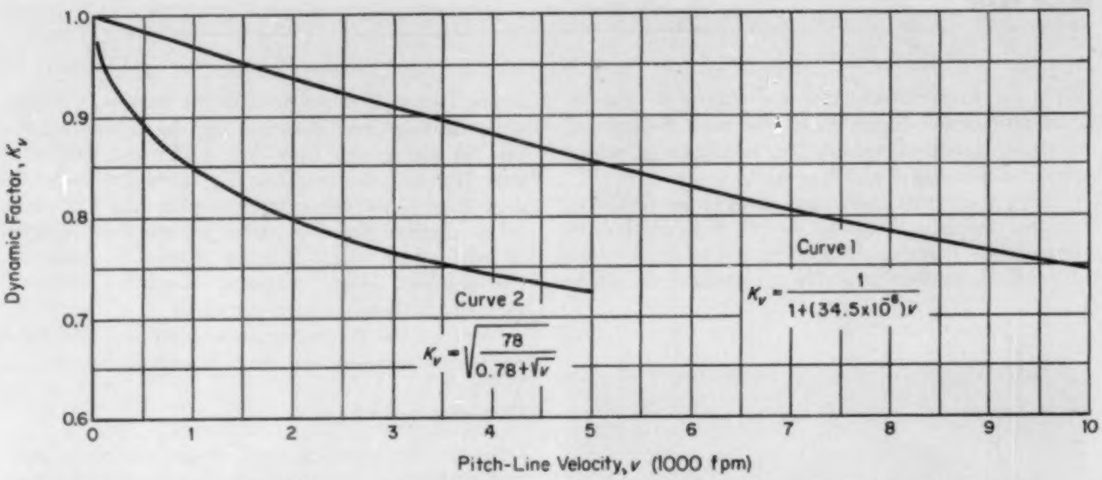


Fig. 2—Helical-gear dynamic factor K_v. Curve 1 applies to high-precision, high-speed applications where deliberate effort is made to reduce dynamic disturbances to a minimum through the use of fine pitches, a face-width to axial-pitch ratio of 3 or more, dynamically balanced rotating elements, and precision bearings with minimum clearances. Curve 2 applies to many commercial gears when dynamic loads can be expected.

to be used for calculating K_m.

$$Z = \frac{1}{2}\left[\sqrt{D_o^2 - D_b^2} + \sqrt{d_o^2 - d_b^2} - \sqrt{D^2 - D_b^2} - \sqrt{d^2 - d_b^2}\right]$$

Values for these symbols are included in the initial gear data; therefore, Z = 0.474 in. Next,

$$p_b = \frac{\pi d_b}{N_P} = 0.263$$

Finally,

$$\frac{Z}{p_b} = 1.78$$

11. Determine load-distribution factor K_m. This factor is determined by successive approximations since it is a function of load. A recommended procedure is as follows: Express W_t in terms of C_e and known factors. Therefore,

$$e = 0.0005 + \frac{0.0002\,W_t}{1000} \text{ (stated initially)}$$

By definition,

$$C_e = \frac{W_t}{1000\,e} = \frac{W_t}{(0.5 + 0.0002\,W_t)}$$

Or,

$$W_t = \frac{500}{\frac{1000}{C_e} - 0.2}$$

Equate values of W_t from this equation and earlier one for W_t:

$$\frac{1815}{K_m} = \frac{500}{\frac{1000}{C_e} - 0.2}$$

Or,

$$K_m = 3.63\left[\frac{1000}{C_e} - 0.2\right]$$

Next, assume values for C_e, obtain K_m from Fig. 5, and compare with the calculated K_m. Since $K_m > 1$ and is finite, $1 < C_e < 2100$. In Fig. 5, $1.25 < K_m < 5.0$; hence, the range of C_e must be 635 to 1835. Assume a value midway between 600 and 1800 for the first approximation. If the calculated K_m is greater than the approximated K_m, then the alignment error will allow more contact and a greater C_e must be assumed.

Approx.	Assumed C_e	F_m	F_m/F	K_m	Calc. K_m
1	1200	1.60	1.07	1.90	2.30
2	1600	1.80	1.20	1.70	1.54
3	1450	1.70	1.13	1.80	1.78

Use the calculated value, $K_m = 1.78$.

12. Determine rated capacity P_{at}.

$$P_{at} = \frac{46.8}{K_m} = 26.3 \text{ hp}$$

The load which this helical pinion can safely transmit is limited by the AGMA surface durability rating which is 20.6 hp (AGMA Standard 211.01, April 1944). The ratio of AGMA strength rating to AGMA durability rating is 1.28. This method of determining gear-strength rating is recommended for detailed estimates, gear-failure analysis, and research purposes.

Typical load distributions are shown in Fig. 4. Load-distribution factor K_m is the most difficult of all rating factors to evaluate. For detailed suggestions consult References 4 and 5.

Errors sometimes so combine that either less than full face width is in contact or full face width is in contact but nonuniform loading exists. Deflections of teeth themselves partially compensate for these errors. Hence, if total effects of the enumerated variables causing lead deviation can be computed, K_m can be determined from Fig. 5. Errors, tangential load W_t, and the resulting K_m factor are mutually dependent terms requiring successive approximations for a solution. Fig. 5 is useful for research purposes or when particularly detailed studies are required. For general design purposes, simplified alternate methods are being successfully used.

Most helical and herringbone-gear sets will have K_m values between the limits shown in Fig. 6.

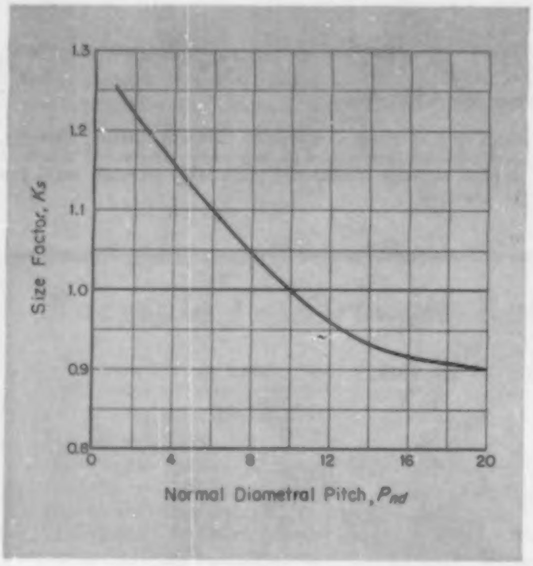


Fig. 3—Size factor K_s for carburized gears. Effective case depths are assumed to be between 1/5 and 1/7 of normal tooth thickness.

Geometry factor J . . .

measures the effect of tooth shape, the worst position of loading, the stress concentration at the root, the moment correction for relative position of load application, and the mode of load distribution along the oblique lines of helical contact. The geometry factor includes various geometric relations, among them the term, cos ψ, which permits use of transverse diametral pitch rather than normal diametral pitch in the stress and power formulas.

Geometry factor J is defined as:

$$J = \frac{Y_c \cos^2 \psi}{K_f m_N} \qquad (4)$$

Helical tooth-form factor Y_c . . .

accounts for bending strength of the teeth. For helical gears, the worst position for highest stress is usually with corner loading which occurs when the oblique line of contact intersects the top edge of the tooth, Fig. 7. Form factor Y obtained for tip loading

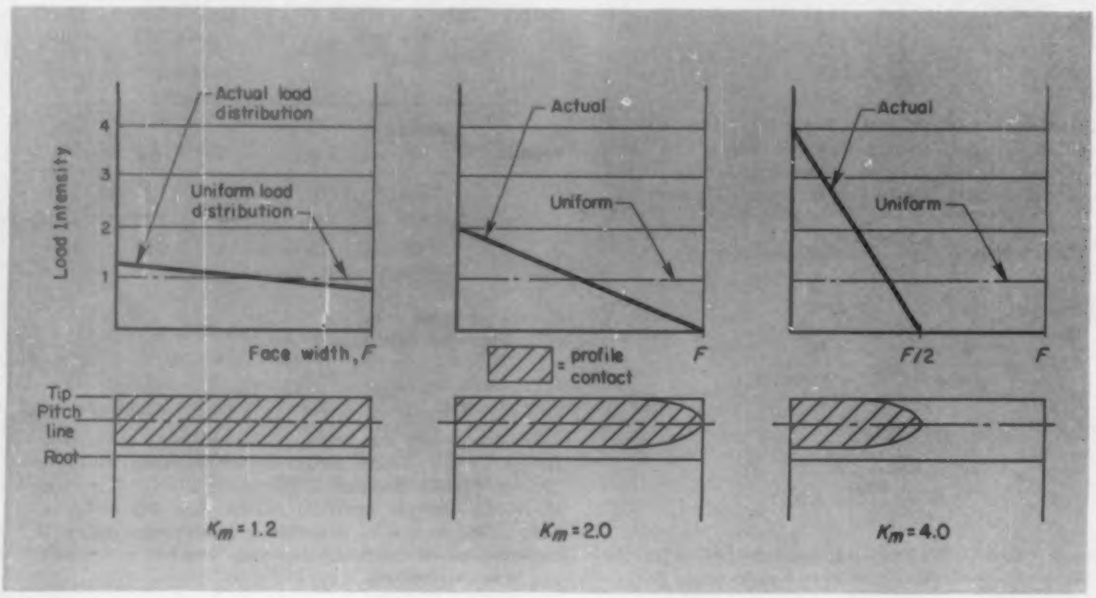


Fig. 4—Contact patterns and load distributions.

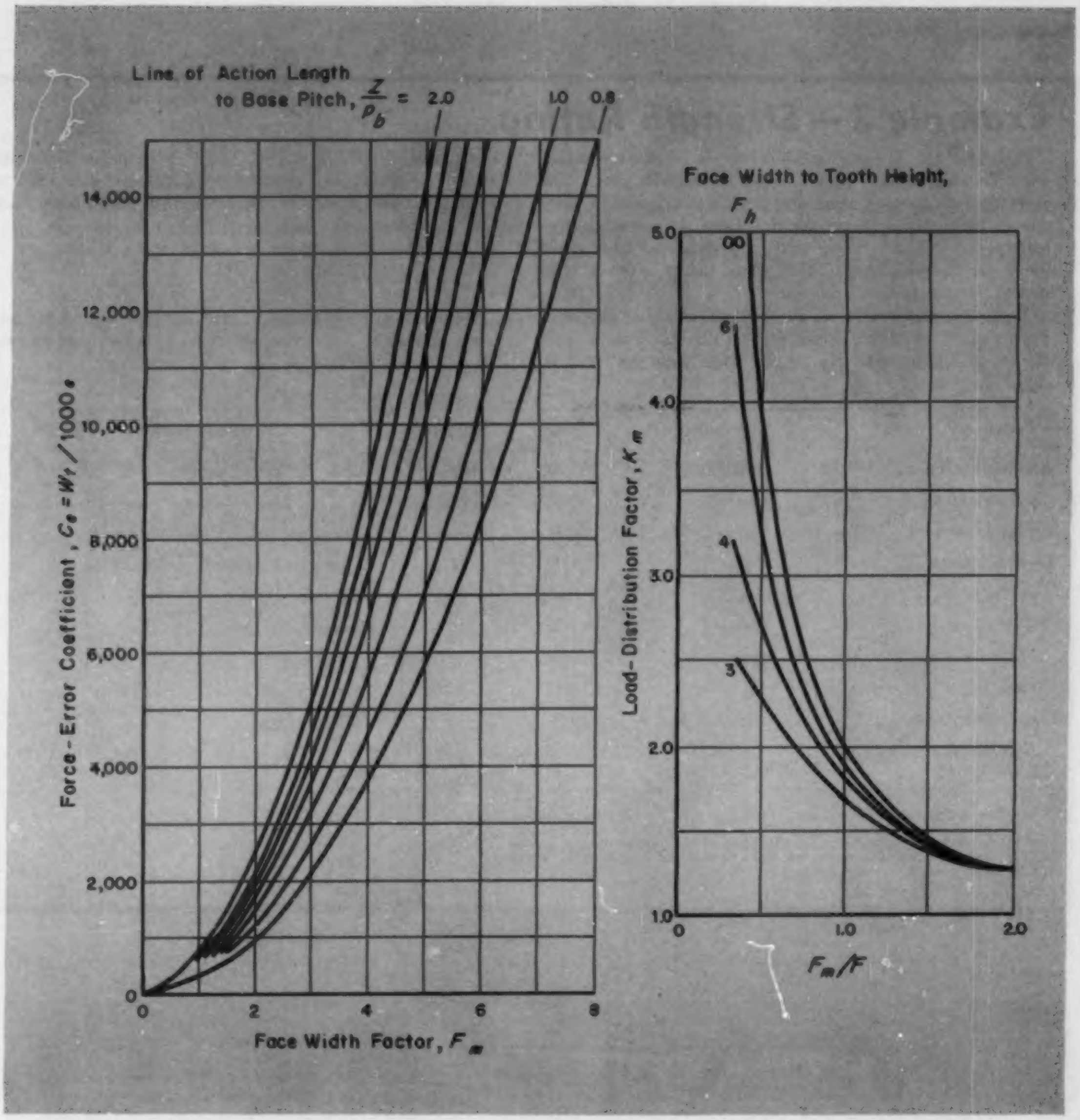


Fig. 5—Helical-gear, load-distribution factor K_m. Example 1 demonstrates how to use these charts.

moment, as used in the classical Lewis beam concept, can be corrected by helical factor C_h, Fig. 8, so as to conform to the cantilever-plate theory which correctly applies.[4] Hence,

$$Y_c = \frac{1}{\frac{\cos\phi_{Ln}}{\cos\phi_n}\left(\frac{1.5}{XC_h} - \frac{\tan\phi_{Ln}}{t}\right)} \tag{5}$$

Definitions of terms and instructions for the computation of Y_c are given in the Appendix.

Stress-correction factor K_f . . .

involves the conventional stress concentration due to the geometric proportions of the root fillet. It also includes the effect of the stress system in the vicinity of the root due to location of load, plasticity effects, residual stresses, materials composition, surface finish, rim stiffness, etc. Most gear designers use the photoelastic stress-concentration factors developed by Dolan and Broghamer:

$$K_f = H + \left(\frac{t}{r_f}\right)^J \left(\frac{t}{h}\right)^L \tag{6}$$

Terms r_f, t, and h can be obtained from the dimensions computed in the Appendix. Values of H, J, and L are as follows:

Pressure Angle (deg)	H	J	L
14½	0.22	0.20	0.40
20	0.18	0.15	0.45
25	0.14	0.11	0.50

Example 2 — Strength Rating

Determine the strength rating of the set of case-carburized gears detailed below. Pinion speed $n_P = 450$ rpm. The gears do not meet the lead specification for precision gears due to thermal distortions resulting from an operating temperature of 240 F. These gears are employed in a drive for a centrifugal blower. The prime mover is an electric motor. Gear data are as follows:

Transverse diametral pitch $P_d = 15.07$. Normal diametral pitch $P_{nd} = 16$. Face width $F = 1.125$ in. Pinion teeth $N_P = 21$. Gear teeth $N_G = 92$. Gear ratio $m_G = 4.38$. Helix angle $\psi = 19$ deg 40 min. Normal pressure angle $\phi_n = 22$ deg. Pinion operating pitch diameter $d = 1.393$ in. Gear operating pitch diameter $D = 6.107$ in. Pinion hardness = 60 Rc. Gear hardness = 55 Rc.

Geometry factors determined from tooth layouts are as follows: $J_G = 0.540$ and $J_P = 0.533$.

Solution: As in Example 1, find factors required for, and solve, Equation 3 for P_{at}. Selection of factors and calculations are summarized in the following table:

Factor	Source	Gear	Pinion	Remarks
Allowable stress s_{at}	Table 3	55,000	55,000	Gear = 55 Rc, pinion = 60 Rc
Geometry factor J	Layout	0.540	0.533	
Dynamic factor K_v	Curve 2, Fig. 2	0.94	0.94	Pitch-line vel. = 164 fpm
Overload factor K_o	Table 1	1.00	1.00	Uniform load and power source
Size factor K_s	Fig. 3	0.916	0.916	Case-carb. gears, $P_{nd} = 16$
Factor of safety K_R	Table 4	1.25	1.25	Commercial reliability
Life factor K_L	Fig. 13	1.00	1.00	Infinite life
Temp. factor K_T	Eq. 9	1.13	1.13	Reducer, 240 F
Load distr. factor K_m	Curve 2, Fig. 6	1.5	1.5	Not prec. gears
Allowable power P_{at} (hp)	Calc.	5.35	5.28	$d = 1.393$ in., $n_P = 450$ rpm, $F = 1.125$ in., $P_d = 15.07$

The AGMA surface-durability rating is 7.15 hp (AGMA Standard 211.01, April 1944). The ratio of AGMA strength to AGMA durability = 0.74. Therefore, the strength rating is the critical rating for the gear set. The gears are more susceptible to a fatigue failure than they are to surface distress.

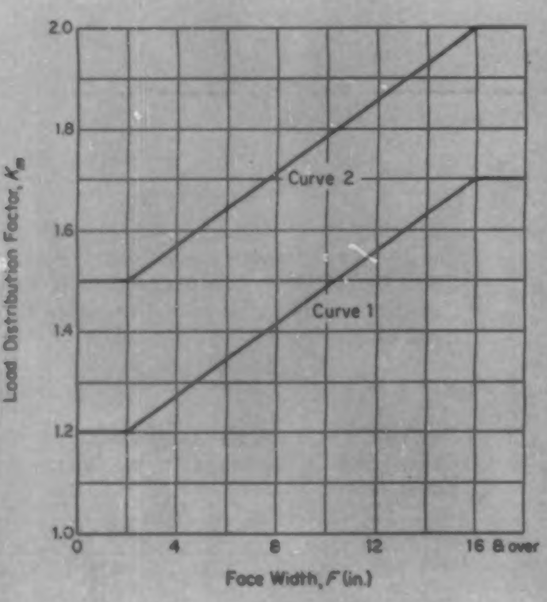
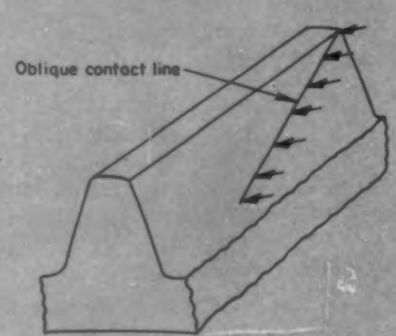


Fig. 6—Probable limits of load-distribution factor K_m. Use curve 1 for gear sets with accurate mountings, small bearing clearances, minimum elastic deformations, precision gears. Use curve 2 for gear sets with less-rigid mountings and less-accurate gears. When less than full face width is in contact, K_m is likely to be 2 or greater.

Fig. 7—Corner loading, the operating condition under which highest stress usually occurs.



Values for other pressure angles can be estimated from these factors.

Certain combinations of fillet size and material hardnesses cause lower stress concentration factors than those given by Equation 6. Correction for steel can be made by using the q value from Fig. 9 and substituting K_p in place of K_f in the geometry factor equation, where

$$K_p = q(K_f - 1) + 1 \qquad (7)$$

The stress-concentration factor varies with the number of cycles and is partially compensated for by life factor K_L.

Load-sharing factor m_N . . .

is a measure of maximum load intensity along the oblique lines of contact. Considering the load divided evenly along these lines of contact,

$$m_N = \frac{F}{L}$$

During all phases of tooth action, the minimum length of the lines of contact varies less than 5 per cent from the average for well-designed helical gears. Hence,

$$L_{min} = \frac{0.95 Z F}{p_N}$$

Then,

$$m_N = \frac{p_N}{0.95 Z} \qquad (8)$$

A minimum value of m_N probably is $p_N/0.80Z$ and

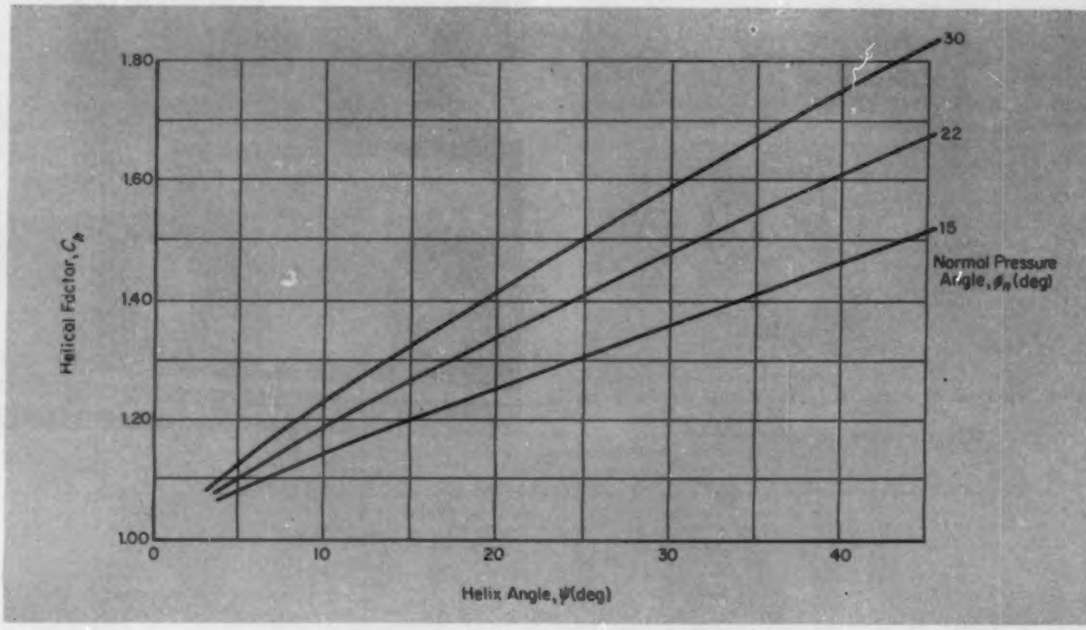


Fig. 8—Helical factor C_h.

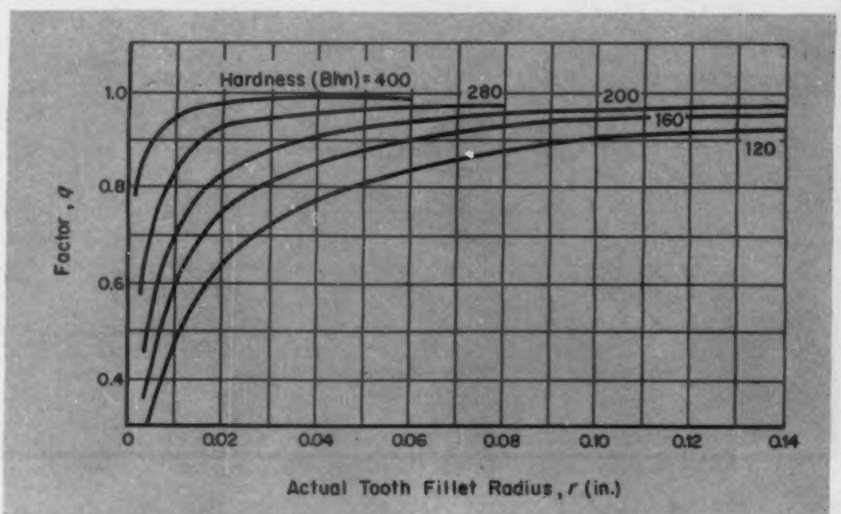
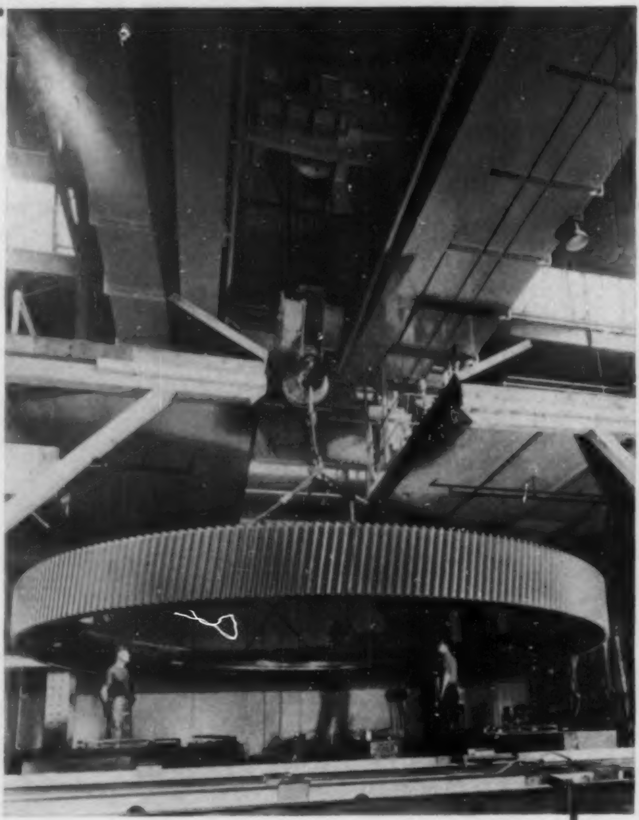


Fig. 9—Size and material stress-correction factor q.



Example 3 — Stress and Factor of Safety

Determine tensile stress at the root of the tooth of the helical pinion specified below. Also, determine factor of safety K_R based on: 1. Allowable fatigue stress. 2. Allowable yield strength.

There is full-face contact under full load. Pinion transmits 1500 hp at 180 rpm. The prime mover is an electric motor and the load is a moderate shock load. Operation is 8-10 hr per day. Gear data are:

Transverse diametral pitch P_d = 1.500. Normal diametral pitch P_{nd} = 1.506. Face width F = 28.00 in. Pinion teeth N_P = 29. Helix angle ψ = 5 deg. Normal pressure angle ϕ_n = 24 deg 55 min. Pinion operating pitch diameter d = 19.250 in. Gear operating pitch diameter D = 213.084 in. Pinion hardness = 225 Bhn min. Geometry factor J, from a tooth layout, = 0.606.

Solution: Select the basic equations: For bending stress s_t, Equation 1; for factor of safety,

$$K_R = \frac{s_{at}\,K_L}{s_t\,K_T}$$

or

$$K_R = \frac{s_{ay}\,K_L}{s_t\,K_T}$$

For selections of factors and calculations, see the following table:

Factor	Source	Value	Remarks
Trans. tang. load W_t (lb)	Calc.	54,500	W_t = 126,000 $P/n_P d$ = 126,000 (1500)/180(19.250)
Overload factor K_o	Table 1	1.25	Uniform power, moderate shock load
Dynamic factor K_v	Curve 2, Fig. 2	0.84	Pitch-line velocity = 910 fpm
Size factor K_s		1.00	
Load distribution factor K_m	Intermed. value, Fig. 6	1.8	Full-face contact under full load
Geometry factor J	Calc.	0.606	
Calc. tensile stress s_t (psi)	Calc.	12,900	P_d = 1.500, F = 28.00 in.
Allowable stress s_{at} (psi)	Curve 2, Fig. 11	29,500	Min. hardness, 225 Bhn
Allowable stress s_{ay} (psi)	Fig. 12	75,000	
Life factor K_L	Fig. 13	1.00	Infinite life
Temp. factor K_T		1.00	Commercial reducers, less than 200 F
Factor of safety K_R	Calc.	2.29 Fatigue	
Factor of safety K_R	Calc.	5.81 Yield	

Table 4 shows that these values for factor of safety indicate high reliability.

should be used when narrow profile or face contact or heavy tip relief is present. For most accurate results, it is better to calculate the minimum total lengths of the oblique lines of contact at the worst position of loading. Simplified geometry-factor curves, such as shown in Fig. 10, can be prepared for ready use in routine design. Reference 5 gives the necessary concepts.

Allowable Stress

The calculated stress cannot exceed an allowable stress modified for the operating temperature, the factor of safety, and the number of operating cycles.

Allowable stress s_{at} and s_{ay} . . .

are usually within the limits shown in Fig. 11 and Table 3. Allowable stresses lower than suggested for general-design purposes are occasionally found when complexity of the part or the heat-treating procedure locks-up undesirable stresses or when material cleanliness or metallographic structure are undesirable.

Reduced allowable stresses up to and occasionally exceeding 20 per cent are required for gears having high hoop stresses developed by heavy interference fits with the shafts, thin rims subjected to high tangential stresses, or keyways located close to the roots of the teeth.

When only static or infrequent peak loads are

Table 3—Allowable Fatigue Stress

Gear Material	Heat Treatment	Allowable Fatigue Stress, s_{at} (psi)
Steel (Also see Fig. 11)	Case carburized, 55-63 Rc	55,000-65,000
	Nitrided AISI 4140, case 53-55 Rc	35,000-45,000*
	Flame hardened	†
Cast Iron		
AGMA Grade 20	....	5,000
AGMA Grade 30	175 Bhn min	8,500
AGMA Grade 40	200 Bhn min	13,000
Nodular Iron		
Annealed	65,000 psi min	Use 75-85 per cent of the value of steel of the same tensile strength (tentative)
Normalized	95,000	
Oil quench and temper	125,000	
	160,000	
Aluminum Bronze		
ASTM-B-148-52, alloy 9C-H.T.	90,000 psi min	20,000-25,000 (tentative)

*At the higher stress, chipping or spalling may be encountered.

†For the hardness pattern of (a) use either 90 per cent of the stress value of steel with a hardness equal to that at the root or 55,000 psi, whichever is smaller.

For the hardness pattern of (b) use 70 per cent of the stress value of steel with hardness equal to that at the root of the tooth.

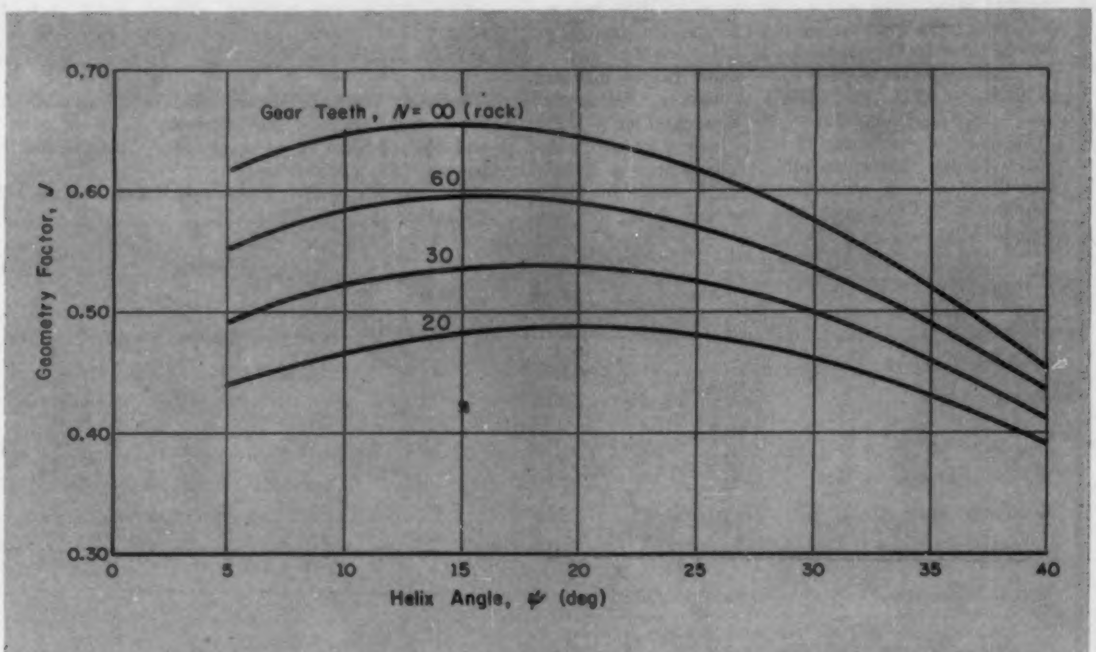


Fig. 10—An example of simplified curves for geometry factor J, normal pressure angle $\phi_n = 22$ deg.

transmitted, the allowable working stress is yield stress s_{ay}. If this stress is exceeded, the teeth will usually bend and will undoubtedly fracture during subsequent operation. When yield is the governing stress, the stress-concentration factor is sometimes not effective.

Fig. 12 shows allowable s_{ay} values frequently used. If tensile-test data or other more accurate data regarding the yield strength are known, they should be substituted.

Life factor K_L . . .

can not be precisely set to allow for a finite number of cycles. Since gear teeth are elastic members and consequently develop a load distribution dependent upon the absolute degree of loading, it is valid to conclude that the stress developed in gear teeth is not directly proportional to the load. Furthermore, the stress-concentration and correction factors might also vary with load.

Values for life factor K_L shown in Fig. 13 can be used as a guide. Laboratory tests seem to indicate that these are conservative.

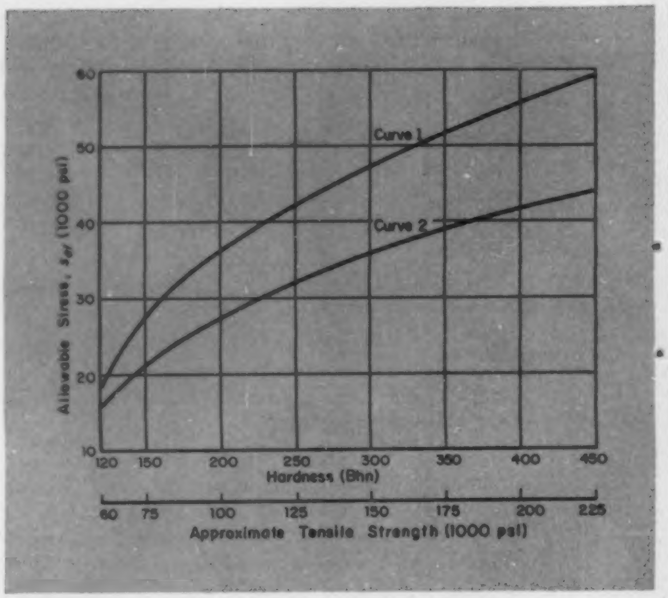


Fig. 11—Allowable fatigue stress s_{at} for steel gears. Curve 1 applies for exceptionally good forging, rolling, casting, and heat-treating procedures. Curve 2 is useful for general-design purposes.

Example 4 — Service Rating

Determine the service rating for strength of the gear set specified below. The pinion is driven by an 1800-rpm electric motor. The gears operate 10 hr per day, 260 days per yr. Service factor for the application is 1.25. Gear data are:

Transverse diametral pitch P_d = 6.546. Normal diametral pitch P_{nd} = 6.932. Face width F = 4.063 in. Pinion teeth N_P = 44. Gear teeth N_G = 101. Gear ratio m_G = 2.295. Helix angle ψ = 19 deg 12 min. Normal pressure angle ϕ_n = 22 deg. Pinion operating pitch diameter d = 6.676 in. Gear operating pitch diameter D = 15.324 in. Pinion hardness = 285 Bhn min. Gear hardness = 245 Bhn min.

Ratio of face width to axial pitch = 2.93.

Gear accuracy and mounting are good, typical of precision gears. Good material quality is insured by rigid casting and heat-treating procedures.

Solution: The basic power formula is Equation 3. Since service factor is used, life factor K_L, factor of safety K_R, and overload factor K_o are equal to one. Then service horsepower = P_{at}/service factor.

For selection of factors and calculations, see the following table:

Factor	Source	Gear	Pinion	Remarks
Allowable stress s_{at} (psi)	Curve 1, Fig. 11	42,000	46,000	Gear = 245 Bhn min, pinion = 285 Bhn min
Geometry factor J	Fig. 10	0.610	0.57	ϕ_n = 22 deg, ψ = 19 deg 12 min
Dynamic factor K_v	Curve 1, Fig. 2	0.91	0.91	Face/axial pitch = 2.93. Pitch-line velocity = 3150 fpm
Size factor K_s		1.00	1.00	
Temp. factor K_T		1.00	1.00	Commercial reducer, less than 200 F
Load-distr. factor K_m	Curve 1, Fig. 6	1.28	1.28	Gear accuracy and mounting are good
Allowable power, P_{at} (hp)	Calc.	1080	1107	d = 6.676 in., n_P = 1800 rpm, F = 4.063 in., P_d = 6.546
Service horsepower	P_{at}/service factor	863	885	SF = 1.25

The load this gear set can safely transmit is limited by the AGMA surface durability rating which is 388 hp at service factor = 1.0 (AGMA Standard 211.01, April 1944). The ratio of AGMA strength to AGMA durability = 2.78 which indicates strength need not be given further consideration.

For drives operating for various number of cycles at different loads, it is the author's experience that operation below the fatigue limit seemingly does not contribute to a decreased life at the higher loads. Cumulative fatigue damage phenomenon for gear teeth is not yet well known.

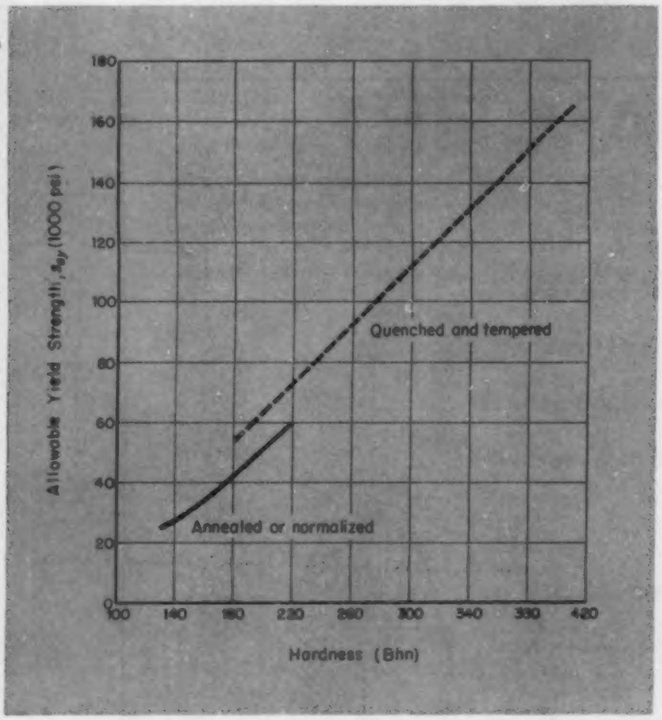


Fig. 12—Allowable yield strength s_{ay} for steel gears.

Factor of safety K_R . . .

covers the unknowns in the various rating factors, the spread or scatter of materials properties, and the concepts of statistical reliability now widely used. It is well for a designer to keep records of his gear designs and applications to determine the factors of safety most applicable. They vary with the quality of the gear manufacture, service conditions, formula manipulations, and factor selections used to rate the gears.

When the factors are conservatively selected or based upon reliable information, the factors of safety shown in Table 4 can be used.

Temperature factor K_T . . .

evaluates the effect of temperature on the material—

Table 4—Factor of Safety K_R

Requirement of Application	Allowable Stress s_{at}	Allowable Stress s_{ay}
Highest reliability Probability of failure practically nil.	2.00 or over	3.00 or over
Commercial reliability	1.25*	1.33
Failure frequency (per cent)		
1	1.00	†
20	0.80	†
33	0.70	0.75

*Partially compensates for occasional wear or damage normally expected in service.

†Exact value will depend upon statistical distribution of the properties. The value shown for 33 per cent failures is based upon steel produced and heat treated by conventional commercial procedures.

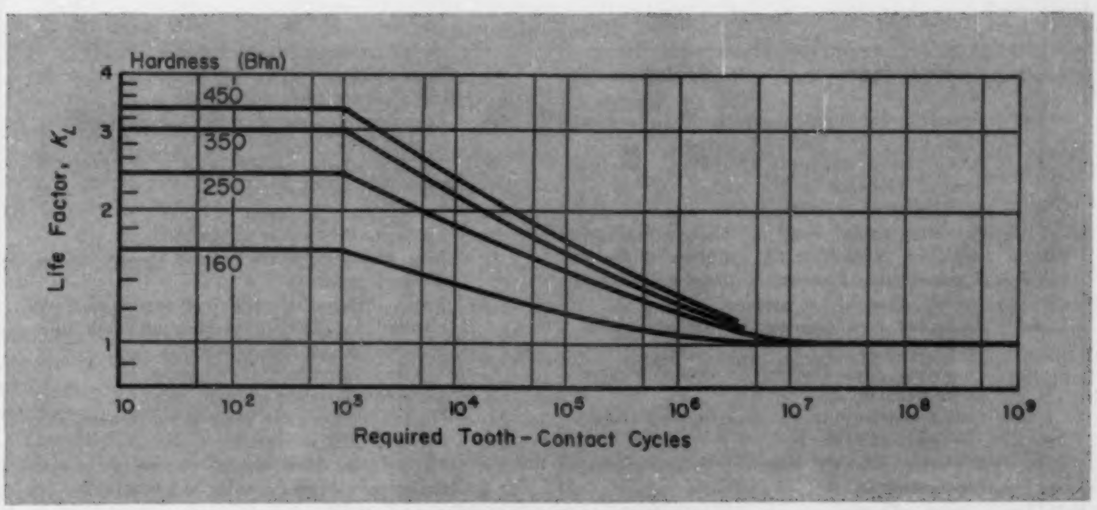


Fig. 13—Life factor K_L for steel gears.

lowering of properties and distortion of the blanks. No correction is usually applied—$K_T = 1$—when the blank temperature does not exceed 250 F. Case-carburized gears operating above 160 F are sometimes corrected as follows:

$$K_T = \frac{460 + T_F}{620} \qquad (9)$$

where T_F = peak operating temperature (F) of oil.

REFERENCES

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2. AGMA 221.02, "Tentative AGMA Standard for Rating the Strength of Helical and Herringbone Gear Teeth," American Gear Manufacturers Association, Washington, D. C.
3. A. Seireg and E. J. Wellauer—"Bending Strength of Gear Teeth by Cantilever-Plate Theory," *ASME Trans.*, Vol. 82, Series B, No. 3, pp. 213-222, August, 1960.
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5. E. J. Wellauer—"Strength Rating of Helical Gears—Derivations, Factors, Examples," AGMA Paper 229.04, June, 1960, American Gear Manufacturers Association, Washington, D. C.
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Appendix

Values necessary for helical tooth-form factor Y_e and other dimensions useful for the determination of geometry factor J can be obtained either by a layout or by a manual or computer-programed calculation. Data presented here are for the scale layout shown.

A generated layout is required of the tooth profile in the normal plane at a scale of one diametral pitch (P_{nd}). The tooth layout is made for the *equivalent* number of teeth.

The involute profile curve can be developed by any of the conventionally used procedures.

The following computations are required to determine factors to be used in Equation 5 for Y_e:

$$N_e = \frac{N}{\cos^3\psi}$$

$$d_e = N_e$$

$$a = \frac{d_o - d}{2} P_{nd}$$

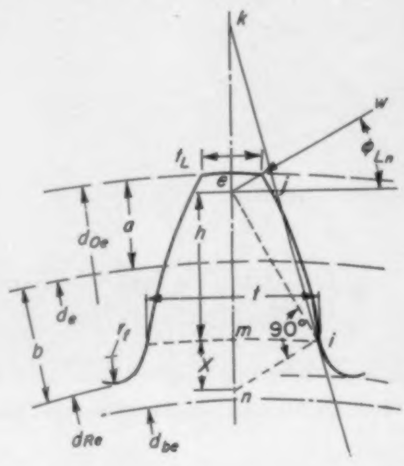
$$b = \frac{d - d_R}{2} P_{nd}$$

$$d_{be} = d_e \cos\phi_n\,, \quad d_{oe} = d_e + 2a\,, \quad d_{Re} = d_e - 2b$$

$$\phi_{Ln} = \cos^{-1}\frac{d_{be}}{d_{oe}} - 57.3\,\frac{t_L}{d_{oe}}$$

$$r_f = \frac{(b - r_T)^2}{\dfrac{d_e}{2} + b - r_T} + r_T$$

The procedure for computing stress-correction factor K_f is as follows: Minimum generated fillet radius r_f, tangent to the root circle, is used to determine stress-correction factor K_f. Having obtained dimensions t, h, and r_f, calculate t/h and t/r_f. Determine the stress-correction factor by using Equations 6 and 7.



Helical-tooth form-factor layout to determine Y_e.

Nomenclature

- a = Generated addendum to one normal diametral pitch, in.
- b = Generated dedendum to one normal diametral pitch, in.
- C_h = Helical factor, the ratio of the root bending moment produced by tip loading to the root bending moment produced by the same intensity of loading applied along the oblique helical contact line. Values for C_h are given in Fig. 8.
- d = Standard pitch diameter, N_P/P_d, for the actual number of teeth and generated pitch, in.
- d_{be} = Equivalent base diameter for equivalent number of teeth, in.
- d_e = Equivalent pitch diameter for equivalent number of teeth, in.
- d_o = Outside diameter for the actual number of teeth and generated pitch, in.
- d_{oe} = Equivalent outside diameter for equivalent number of teeth, in.
- d_R = Root diameter for the actual number of teeth and generated pitch, in.
- d_{Re} = Equivalent root diameter for equivalent number of teeth, in.
- N = Actual number of teeth
- N_e = Equivalent number of teeth
- P_{nd} = Normal diametral pitch
- r_f = Minimum fillet radius at root circle, in.
- r_T = Edge radius of generating hob to one normal diametral pitch, in.
- t = Tooth thickness at section of maximum stress obtained by constructing kji tangent to fillet curvature at i so that $kj = ji$, in.
- t_L = Tip thickness measured from layout, in.
- X = Distance mn measured from layout, in.
- ϕ_{Ln} = Normal load pressure angle at tip of tooth, deg
- ϕ_n = Tooth normal pressure angle, deg
- line we = Normal load line, tangent to equivalent base circle for equivalent number of teeth

A designer's guide to

THERMAL STRESSES

Part 4—Stresses and Strains

- ***Residual Stress***
- ***Strain Concentration***
- ***Surface Protection***

S. S. MANSON
Chief, Materials and Structures Research Div.
Lewis Research Center, NASA
Cleveland, Ohio

IN addition to the factors discussed in Part 3 of this series, there are other means available to the designer for reducing the ill effects of thermal stress. These means include setting up residual compressive and tensile stresses, guarding against stress concentrations, and providing adequate surface protection.

Residual Stress

Frequently, residual stresses result from temperature nonuniformities during the manufacture or processing of a machine part. These stresses may seriously affect the strength of the part in service, whether the loading is mechanical or thermal.

The detrimental effect is more serious in brittle materials, in which the service stresses add directly to the residual stress with no relief through creep or plastic flow. On the other hand, it is possible to purposely incorporate residual stresses opposite to the operating thermal or mechanical stresses, and thus strengthen the part.

Beneficial Stresses: In many cases, thermal-shock resistance of a part can be improved by introducing stresses to counteract the thermal stresses. Induced compressive stresses have been used to improve mechanical-fatigue characteristics at room temperature. The same basic methods can also be used for parts operating at high temperature, provided that the temperature is not high enough to anneal the induced stresses. There are several ways of inducing beneficial stresses to counteract undesirable thermal stresses.

MECHANICAL LOADINGS: Prestressed concrete is an illustration of a residual-stress system set up through mechanical loading. The reinforcing steel rods are loaded to the desired tensile stress, and the

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concrete is poured around the rods. When the concrete has hardened, the load is released, and the rods tend to contract. Full contraction is prevented, however, by the surrounding concrete, which is thus placed in compression. Compressive service loads add, of course, to the residual compression, reducing the load-carrying capacity in compression.

Another example of a residual stress induced through mechanical loading is a press fit in a machine part. Force applied during assembly stretches one member and compresses the other, forcing the fit. The stretched part is left under residual tension, the compressed part under residual compression.

Differential Plastic Flow: The natural length of one element of a body can be increased or decreased by subjecting it to plastic flow, while the length of other elements are not changed. "Accommodation" of deformed elements into the system introduces residual stresses. One of the best-known methods of inducing such stresses is shot peening. This method causes the surface of the part to stretch plastically, but full elongation of the surface elements is constrained by the subsurface layers, which are not stretched. The stretched surface elements are thus forced into residual compression. This compression is beneficial in fatigue applications involving surface tensile stresses.

Differential Temperature: If during the fabrication or assembly of a part the various elements are maintained at different temperatures, subsequent temperature equalization will cause initially hot elements to contract, exerting forces on initially cool elements. Thus, the initially hot elements will be placed in tension, since they are not permitted to contract fully. Conversely, the initially cool regions will be placed in residual compression.

A simple shrink fit illustrates this method. A sleeve is machined with an ID slightly less than the OD of its cylinder. The sleeve is then heated to permit at least a slip fit. After the two parts have been fitted together, the sleeve is permitted to cool. An interface pressure develops which causes residual tension in the sleeve and residual compression in the cylinder.

Tests have been carried out on the thermal-shock characteristics of ceramic cylinders for use in rocket nozzles.[1] The method finally decided upon, essentially a shrink fit, consisted of spraying a metal coating over the outside of the ceramic cylinders. As the particles of molten metal strike the cold surface of the cylinder, they contract in all directions, inducing compressive stresses in both the axial and the circumferential direction. Whereas the untreated specimens were unsatisfactory, the treated specimens did not fail. Tests have shown, however, that there is an optimum metal thickness, beyond which the beneficial effect is small, Fig. 16.

Another example of a shrink fit can be found in

[1]References are tabulated at end of article.

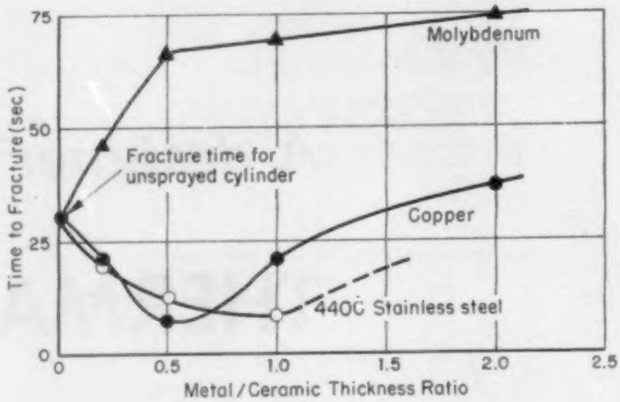

Fig. 16—Effect of metal/ceramic thickness ratio on thermal-shock resistance of ceramic cylinders sprayed with molybdenum, copper, and stainless steel. Data were obtained at 1300 C. Note that as copper and 440 C coatings are sprayed onto the cylinder, the beneficial effects do not immediately appear.

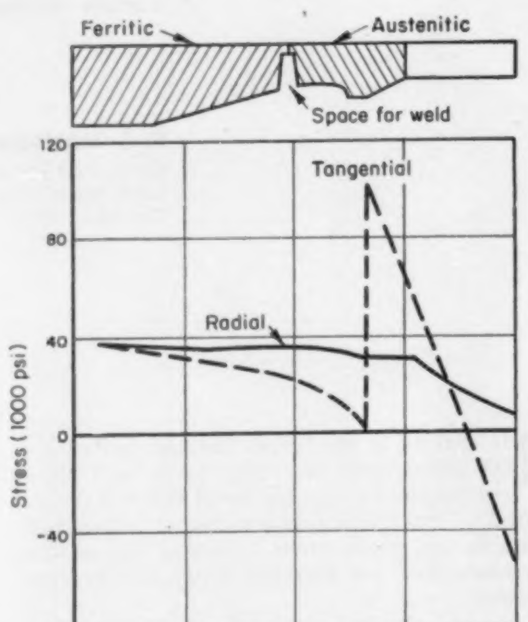

Fig. 17—Cross section of turbine wheel made up of two parts welded together. The rim region is generally preheated before welding. As it cools, beneficial residual stresses are set up. Without this treatment, stresses would be 60,000 psi at the center, and 100,000 at the rim.

turbine wheels. Here, it is desirable to introduce a residual tensile stress to counteract compressive operating stresses. This can be done by constructing the wheel in two parts, Fig. 17. The outer rim is generally made of austenitic material, the central region of ferritic material. The two parts are welded, as shown. One practice is to heat the rim region to a higher temperature than the central region before welding. When the rim cools it sets up tensile stresses at the rim, and compressive stresses at the center.

Although this approach appears to have merit when only elastic stresses are considered, there is some question as to its validity when operation involves cyclic plastic flow. Strain range depends primarily on the cyclic-temperature profile, and not on any residual stresses that may initially be present. The residual stresses will alter the path whereby the asymptotic strain range is approached, but it should not alter appreciably the magnitude of the strain range finally developed. Hence, there may be some question as to the merit of residual stresses in ductile materials undergoing large amounts of plastic flow per cycle. On the other hand, there are still many unknowns in the assumptions concerning the asymptotic stress-range/strain-range

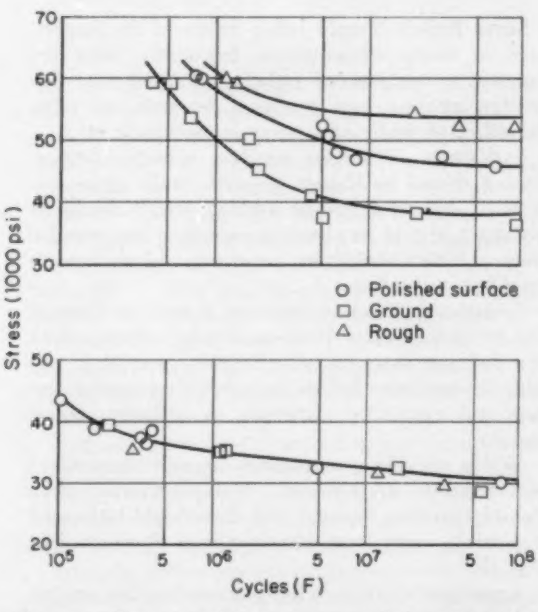

Fig. 18—Effect of surface treatment on fatigue properties of low-carbon N-155 steel. Upper curves were taken at 80 F, bottom curves at 1350 F. At 1350 F, the specimens have virtually identical characteristics, regardless of surface condition, indicating that all beneficial residual stresses have been eliminated.

characteristic for a material having an initial residual stress.

Until experimentally demonstrated otherwise, it may safely be assumed that initial stresses are beneficial when they counteract the operating stresses. For highly brittle materials, in any case, this approach would appear to be satisfactory.

Stress Relaxation: The detrimental or beneficial effects of prestressing can persist only if operating temperatures are not high enough to cause relaxation of these stresses. No data are available on the subject of stress relaxation as applied particularly to the subject of thermal stress. However, investigations have been conducted in connection with high-temperature fatigue.

A program[2] has been conducted to determine the effect of surface finish and surface working on the fatigue properties of low-carbon N-155 alloy, Fig. 18. It was found that the specimen with a roughened surface had a greater strength than the polished and the ground specimens. While this result is contrary to normal fatigue-test findings, the improvement in the rough specimen was attributed to cold work induced in the surface by the roughening process. So much cold work was induced that the detrimental effect of surface irregularities was overcome, and the net effect was beneficial.

Similar specimens were subsequently tested at higher temperatures and the beneficial effect of roughening was found to be reduced. At 1350 F, specimens had essentially the same strength, regardless of surface condition. Thus, at 1350 F all the beneficial effects of cold working were annealed. For further verification of this conclusion, specimens were held in the three surface conditions at 1400 F for 4 hours and were then tested at room temperature. It was shown that holding the material at the high temperature had removed the beneficial residual stress. These results emphasize the importance of operating temperature on the effectiveness of any prestressing operation.

Strain Concentration

Stress and strain concentrations resulting from geometric discontinuities are as important in thermal-stress applications as they are when stresses are mechanically induced—and in some cases more so. When the total thermal expansion must, for example, be absorbed by a light and a heavy section in series, most of the strain may be absorbed in the light section.

It is thus important for the designer to be aware of the common situations in which stress and strain concentrations arise, as well as methods available for overcoming their effect. These methods include: Exclusion, reinforcement, and stress-relief cutouts.

Types: Among the geometrical factors that tend

to concentrate strain in thermal loading, are those already encountered in studies of mechanical loading, such as holes and notches. It has been found,[3] for example, that a small hole in a tube under thermal stress may reduce the life to only one-tenth of normal life. Corresponding reductions have been found in the cyclic life of thermally cycled circular plates, when notches were machined on the periphery.[4]

SHARP CHANGES IN CROSS SECTION: These have long been known to cause stress concentrations in mechanical loading. When the loading is thermal, the effect may be even worse. Not only does strain tend to concentrate in the weakest section, but a thin section has lower thermal inertia than the heavy section. It may get hot or cold faster than the heavy section, thereby inducing a greater differential thermal expansion. In the case of heating, the higher temperature also reduces the yield point at the thin section, so that there is a further tendency to concentrate the strain in this section.

Cases of excessive section gradient are not always obvious. In a turbine bucket, for example, the taper in the axial direction may be gradual, and at first appearance there may be no question of sharp section gradient. But if the leading edge is quite thin compared to the core, the section gradient in the direction of the chord may provide a very effective stress concentration. This is because of the high heating rate of the leading edge relative to the remainder of the cross section.

HOT-SPOTS: These, along with cold-spots, may result in highly localized concentrations of stress or strain. This is true whether hot spots or cold spots are caused by geometric factors, or by aerodynamic or thermodynamic factors.

SURFACE FINISH: This factor is very important in determining the behavior of materials in thermal, as well as mechanical, fatigue. In part, the effect of surface finish is due to residual stresses induced during the finishing process—for example, residual compressive stresses induced during polishing. But a major influence of surface finish is its effect on the stress and strain concentrations produced by surface irregularities.

Table 2—Shock Resistance of Ceramic-Coated Cermet

Treatment Before Thermal Shock		Failure Temp., No Coating (F)	Failure Temp., Two Coats (F)
400 hr at	1650 F	1300	over 2200
200	1800	1200	over 2200
100	2000	1500	over 2200
50	2200	1600	2200

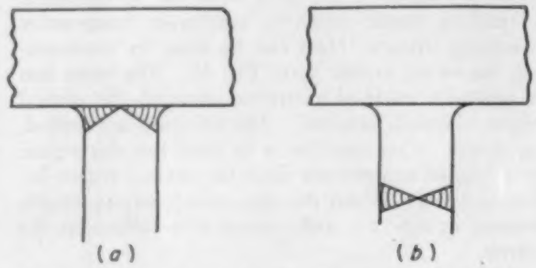

Fig. 19—One method of avoiding the strain concentrations inherent in most welds. The weld shown in *b* is preferable to *a*, because it is located away from a geometric discontinuity.

In thermal-stress fatigue, the importance of this variable may be even greater than in mechanical fatigue. Not only do the higher temperatures frequently involved in thermal-stress applications tend to embrittle the materials—thereby exaggerating the importance of discontinuities—but these temperatures also frequently occur in conjunction with corrosive fluid environments which, through chemical attack, further exaggerate the effect of surface discontinuities.

Stress Relief: Simply being aware of the importance of strain concentration frequently helps the designer to avoid many pitfalls. A number of preventive measures are available, however, to offset the effect of undesirable strain concentrations.

EXCLUSION: Wherever possible, geometric proportioning should be chosen to avoid strain concentrations. Cut-outs should be avoided, and if absolutely necessary, should be placed in regions of low nominal strain. Fillets should be generous, and changes in cross-section gradual.

Sometimes, discontinuities are present as flaws in the structure, rather than as design features which the designer can control. In such cases it is possible to minimize failure by specifying careful surface and subsurface inspection in critically stressed regions.

Welds are likely to contain imperfections which will serve as strain-raisers. Full-penetration welds should, therefore, be used, and they should be located, if possible, away from cross-sectional discontinuities, Fig. 19.

REINFORCEMENT: Where discontinuities are required, it may be possible to reinforce the region of strain concentration by the addition of metal—for example, by a boss around a circular cut-out. But consideration must be given to the effect of the reinforcement on thermal conditions. If, for example, the reinforcement causes a large thermal lag, the strains developed may be increased rather than decreased.

An important case of reinforcement is the build-

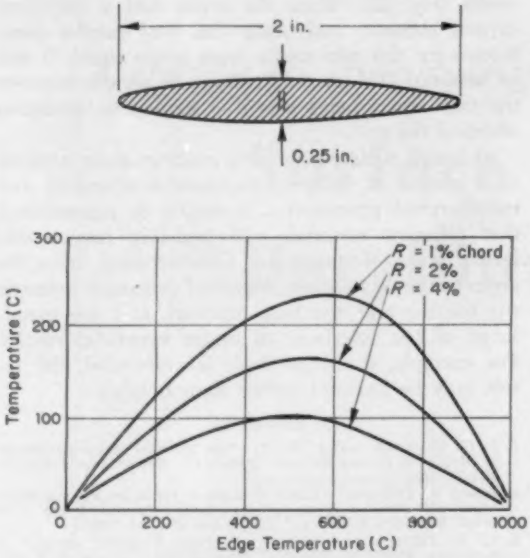

Fig. 20—Effect of edge radius on thermal stress in turbine buckets. The ordinate shows the temperature difference between the edge temperature and mean temperature of an airfoil simulating a turbine blade.

ing up of the thin edges of turbine buckets and discs, Fig. 20. Such thin edges tend to heat up rapidly under the heat-transfer conditions encountered in turbine operation, but are restrained from expansion by the massive bodies to which they are attached. Building them up—that is, using a blunt edge rather than a thin one—results in two important improvements: 1. The rate of heating is reduced. 2. The heavier edge is not as completely constrained from expansion by the cooler core.

Stress-Relief Cutouts: It is sometimes possible to alleviate the high stress concentration in sharp discontinuities by "rounding out" the discontinuity at its critical point, Fig. 21.

Surface Irregularities: Surface irregularities that result during fabrication, or because of lack of attention to important details of surface condition, are often the cause of stress concentrations. In thermal-stress cycling, accelerated fatigue failure may result.

In some cases surface irregularities are not built-in, but are caused by operating conditions. For example, surface attack can produce discontinuities that act as stress concentrations. In an investigation on the thermal-shock resistance of nozzle blades it was found[5] that if the test blades were polished and etched in a mild chemical solution after every 250 cycles, crack resistance was vastly improved. This improvement was attributed largely to the removal of surface irregularities without, however, any appreciable attack on the grain boundaries. Prior tests

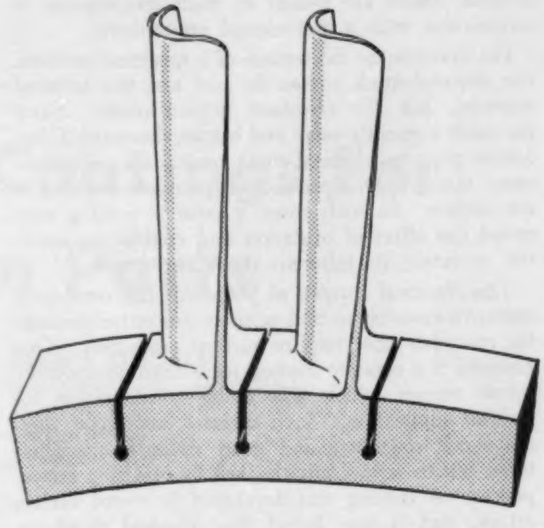

Fig. 21—Aircraft gas-turbine wheel with buckets welded to rim. The notch at the base of each bucket is neutralized by means of a keyhole slot.

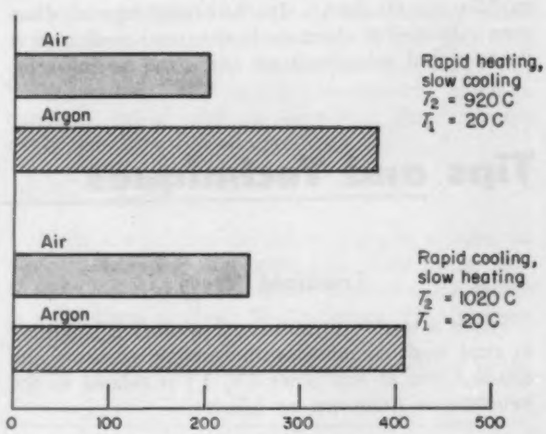

Fig. 22—Effect of environment on endurance of Nimonic 90 under thermal-stress fatigue. Cyclic life is much greater when the parts are fatigued in an inert atmosphere.

in which aqua regia had been used to remove surface scale for inspection had reduced thermal shock resistance of the material and led to early intercrystalline cracking.

Surface Protection

As shown previously, high-temperature operation has a detrimental effect on the metallurgical characteristics of the material. While some of these effects are inherent in high temperature and cannot be

avoided, others are caused by high temperature in conjunction with a detrimental atmosphere.

For example, as the surface of a specimen oxidizes, the thermal-shock cycles do not test the original material, but the resultant surface oxide. Since the oxide is usually weak and brittle, the material becomes poor in thermal-shock resistance. Furthermore, intergranular penetration produces notches at the surface. In such cases, a ceramic coating may retard the effect of oxidation and enable the material to retain its inherent shock resistance.

The National Bureau of Standards has conducted extensive research to find suitable protective coatings for materials that require surface protection. One example is a ceramic coating for a titanium carbide-cobalt cermet which was under consideration for turbine application. Such cermets have good thermal-shock resistance and good strength characteristics, but in service are attacked by oxidizing atmospheres. A coating was developed to retard surface attack, and it was found that thermal shock resistance of coated specimens was much superior to that of uncoated specimens, Table 2.

Further evidence of the value of surface protection can be seen in the results of tests carried out on Nimonic 90 discs.[6] In these tests tapered discs were subjected to alternate heating and cooling in a fluidized bed using both air and argon as fluidizing media, Fig. 22. Since the argon had a very low oxygen content, and since the heat-transfer coefficients for the two media were made equal, it can be assumed that any differences in results between the two atmospheres was due largely to oxidation effects of the air.

Although surface-protective coatings show promise as a means of delaying undesirable chemical and metallurgical phenomena, it should be remembered that different materials will probably require different types of coatings. Consideration must be given to the relative coefficients of expansion between the coating and the base material, and the metallurgy of the interface, to insure beneficial results. For example, if the interface is embrittled, the result may be harmful rather than helpful.

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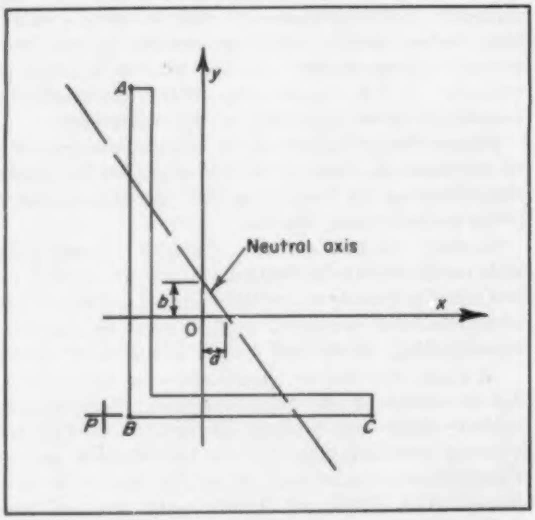
Tips and Techniques

Combined Stress

When a section (symmetrical or not) is subjected to axial loads combined with bending moments, the elastic stress at any point (X, Y) is related to the neutral-axis intercepts as follows:

$$\sigma_{X,Y} = \sigma_{av}\left(1 - \frac{X}{a} - \frac{Y}{b}\right)$$

where $\sigma_{X,Y}$ denotes combined stress at any point in the plane of the section; σ_{av} is the magnitude of the stress at the centroid, which is equal to the average stress on the section (P/A); a and b are the neutral-axis intercepts on the x and y axes; X and Y are coordinates measured from the centroid.



Example: A 10,000-psi compressive load is acting on an 8 x 6 x ½ in. angle as shown. The neutral-axis corresponding to this load position is also given. Compute the stresses at points A $(-1.47, 5.53)$; B $(-1.47, -2.47)$; and C $(4.53, -2.47)$.

From the above, $\sigma_{av} = 10/6.75 = 1480$ psi; $\sigma_A = 1480\,[1 - (-1.47/0.70) - (5.53/1.03)] = -3360$ psi (tension); $\sigma_B = 1480\,[1 - (-1.47/0.70 - (-2.47/1.03)] = +8130$ psi (compression); $\sigma_C = 1480\,[1 - (4.53/0.70) - (2.47/1.03)] = -4560$ psi (tension).—E. Czerniak, *Fluor Corportion Ltd., Los Angeles, Calif.*

A guide to specifying . . .

Surface Coatings For Beryllium Parts

DENNIS O'BOYLE
Gyro Materials Research Engineer
AC Spark Plug Div.
General Motors Corp.
Milwaukee, Wis.

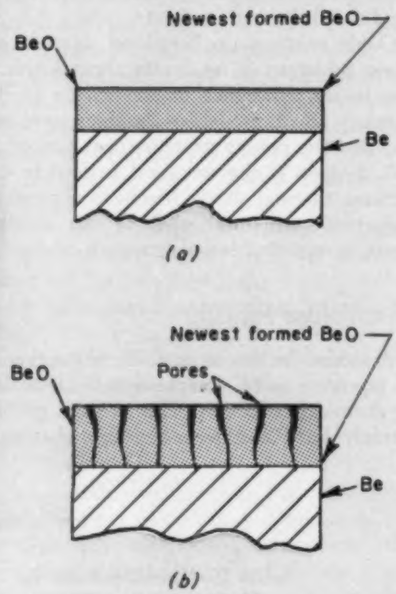


Fig. 1—Formation of oxide layers on beryllium. Natural oxide layer, *a*, is formed on outer surface as beryllium atoms diffuse through oxide layer, and combine with oxygen. In anodized coating, *b*, current passes through pores and liberates oxygen at metal-oxide interface.

LIGHT weight, high strength, and high modulus of elasticity of beryllium have led to its expanding use in commercial and military applications. But even these desirable qualities, Table 1, sometimes fall short of over-all requirements when surface properties are important. Where corrosion or wear are problems, what types of coatings can be considered? This article discusses the coatings currently being used on beryllium, their relative merits, and how they are specified.

Oxide Coatings

When a machined beryllium piece is exposed to the atmosphere, a thin oxide film forms on its surface. At room temperature, this protective film grows to a thickness of about 30 Angstroms. (1 Angstrom = 10^{-8} cm.)

Two techniques are available to produce oxide

Table 1—Properties of Beryllium and Common Metals

Metal	Density (gm/cu cm)	Thermal Expansion (per deg F)	Young's Modulus (psi)	Tensile Strength (1000 psi)
Beryllium	1.85	6.3×10^{-6}	44×10^{6}	80
Aluminum, 2024	2.78	12.0	10.4	66
Titanium, 75A	4.50	4.8	15.4	80
Magnesium	1.80	14.4	6.5	38
Copper	8.94	9.8	17	32
Steel, 4140	7.85	6.2	30	165

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coatings which offer better corrosion protection than the natural oxide film: 1. Oxidation at elevated temperature. 2. Anodic oxidation.

Elevated-Temperature Oxidation: The natural oxide layer on beryllium at room temperature forms by a diffusion-controlled process. When the surface atoms of the pure metal are exposed to air, they combine with oxygen atoms to form a hexagonal beryllium-oxide structure. For this layer to increase in thickness more than a few Angstroms, beryllium atoms from the substrate must diffuse through the oxide layer to combine with oxygen.

At elevated temperatures—500 to 700 F—the increased energy of the beryllium atoms causes rapid diffusion, and an oxide coating several hundred Angstroms thick is formed. Rate of growth of the oxide is parabolic as a function of time, diminishing as the oxide layer increases in thickness.

Anodic Oxidation: A second method used to form a corrosion-resistant oxide film on beryllium is anodic oxidation or anodizing. In this technique, beryllium is made the anode in a suitable electrolytic bath (usually nitric and chromic acid). As a direct current passes through the anode, oxygen is liberated at the surface of the metal and combines with beryllium to form beryllium oxide. Because the newly formed oxide is a nonconductor, the current flows from the solution to the base metal through fine pores in the oxide layer. In contrast to the natural oxide film, which forms at the outer surface of the oxide layer, Fig. 1*a*, the newest anodized layer forms at the interface between the oxide and the base metal, Fig. 1*b*.

Because of its porous nature, the anodized beryllium-oxide coat attains a density of about 75 per cent of theoretical maximum (3.025 gm/per cu cm).[1]

[1]References are tabulated at end of article.

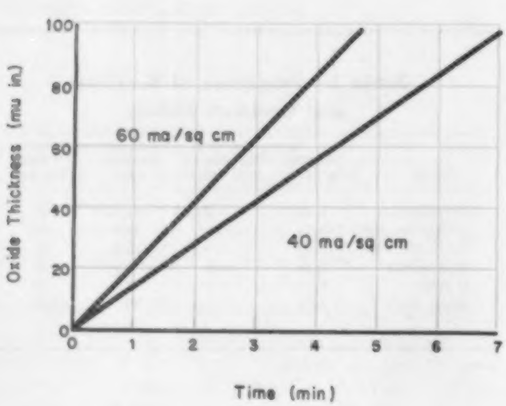

Fig. 2—Early-stage growth rates of anodic oxide coating on beryllium. Parts were electrolytically polished prior to the anodizing treatment.

Oxide density varies throughout the layer, however, being most dense at the surface of the beryllium and least dense at the oxide-acid interface. Because the pores are enlarged at the outermost oxide surface, the surface is less corrosion and abrasion resistant than the oxide in contact with the metal. When the beryllium-oxide coat first begins to form, the relationship between thickness and time, at constant voltage, is linear, Fig. 2.[2] As the oxide layer increases in thickness, however, the dissolving action of the electrolyte becomes important and the new oxide is formed at a slower rate.

Thickness of an anodic-oxide layer on beryllium can be increased by reducing the rate at which the oxide is dissolved in the electrolyte. This is accomplished by either reducing the temperature of the electrolytic bath or by introducing an agent such as carbon dioxide which reduces the corrosiveness of the acid. In either case, control of the bath temperature is necessary since the anodizing process is exothermic. Maximum oxide thickness produced by anodizing is limited to about 2 mils.

Oxide coatings on beryllium do not chip or peel when subjected to moderate shear forces. However, due to the difference in coefficients of thermal expansion (BeO coefficient is about one-half that of Be) and the porous structure of the oxide, fine cracks will develop if the anodized surface is subjected to extreme thermal shock. Mechanical properties of the base metal are unaffected by the anodizing treatment, except that fatigue strength is slightly reduced.

Electroless Plating

A second technique used for protecting the surface of precision metal components is electroless plating, or chemical reduction. This method provides an extremely hard and wear-resistant coating on beryl-

Table 2—Specifications for Plating on Beryllium

Direct Plating

1. Anodic Pickle
   Solution (% by volume): 10% of 85% phosphoric acid; 2% of 38% HCl; bal H_2O
   Current Density: 1 amp/sq in.
   Time and Temp: 2 min at 75 F
2. Chemical Pickle
   Solution: Concentrated nitric acid
   Time and Temp: 2 min at 75 F
3. Acid Dip
   Solution: 100 gm/liter ammonium sulfate; pH2 with H_2SO_4; bal H_2O
   Time and Temp: 1 min at 75 F
4. Electroplate

Zinc-Immersion Method

1. Zinc-Immersion Bath
   Solution (gm/liter): 120 of $Na_4P_2O_7$; 40 of $ZnSO_4 \cdot 7H_2O$; 7.5 of NaF; 5 of K_2CO_3 · pH8 with H_2SO_4 and H_3PO_4
   Time and Temp: 5 min at 180 F
2. Copper Plate
3. Outgas, 30 min in boiling H_2O
4. Cyanide Dip
5. Acid Dip: 3N H_2SO_4 at 75 F
6. Plate

lium by the reduction of nickel salts. Recent refinements in bath composition and in pretreatments for the base metal have made the process efficient for use on a wide range of metals including beryllium. A typical electroless nickel immersion bath for beryllium consists of at least the following ingredients:

- Nickel salts which contribute the nickel ions. Usually nickel chloride or nickel sulfate is used.
- Sodium hypophosphite which reduces the nickel salts to metallic nickel.
- A buffer to neutralize the nascent hydrogen gas. Commonly used buffers are sodium acetate and sodium citrate.

Since no electrodes are used in the plating bath, corner build does not occur and the nickel is uniformly coated on the entire exposed surface, regardless of complexity. Thickness of the deposited coat can vary between 0.0002 and 0.006 in. and is controllable to ± 10 per cent.

The plated metal is an amorphous nickel alloy containing about 6 to 8 per cent phosphorus in solid solution. A precipitation-hardening treatment (aging) may be used to increase the as-plated hardness from 48 to 70 Rockwell C. In the hardened condition, the coating has increased abrasion and wear resistance.

Because of the matched coefficients of thermal expansion (7.2×10^{-6} in./in./deg F for electroless nickel versus 6.3 for beryllium) the coating adheres well to the base metal even when subjected to thermal shock. Use of the coating is limited to service temperatures below 750 F due to softening (overaging) above this temperature.

Electroplating

The most widely used method for protecting a metal surface against corrosion or abrasion is electroplating. Generally, a surface is electroplated either to offer the base material increased surface protection or to improve the appearance of the piece.

Beryllium is electroplated only to improve surface properties, never to improve appearance. Beryllium may be electroplated to: 1. Prevent surface corrosion. 2. Protect the base surface from abrasion and wear. 3. Improve surface conductivity or reduce contact resistance. 4. Prepare surfaces for joining or soldering. 5. Produce a surface capable of taking a fine finish. 6. Protect the base metal during intermittent exposure to high temperature.

To achieve these various functions, a wide range of metals has been electrodeposited on beryllium. Thicknesses range from less than 0.0001 to 0.008 in. Metals which have been successfully plated on beryllium include aluminum, cadmium, chrome, copper, gold, indium, iron, silver, tin, and zinc.

Surface finishes as fine as 1 mu in. rms have been produced on nickel plating over beryllium.[3] Thin deposits of silver or nickel are used to make the surface solderable for joining leads or making other metal attachments.

A disadvantage of thick electroplating on complex parts is the tendency for corner build-up to occur, Fig. 3. This tendency is especially acute when chrome is electrodeposited.

A surface pretreatment is necessary for proper adhesion of the electroplated metal to beryllium. The pretreatment depends on the type and thickness of metal to be deposited. Specifications for two methods used successfully to plate beryllium are shown in Table 2.[3] In both the direct-plating and the zinc-immersion method, a distilled-water rinse is used between each of the steps. Outgassing (Step 3 of the zinc-immersion method) is done after every pickling or plating operation during which hydrogen is liberated. Outgassing prevents hydrogen gas from collecting under the plate and causing blisters. However, when a thick (0.007 in.) nickel plate is deposited over beryllium, the degassing procedure is unnecessary[4]—probably due to the increased strength and stiffness of the thick plate which prevents the formation of blisters.

Flame Spraying

Flame spraying offers maximum protection for

Table 3—Protective Coatings for Beryllium

Coating Method	Thickness Range (in.)	Wear Resistance	Density (gm/cu cm)	Composition of Coating
Oxide Film (natural and high temp)	30 to 2000*	Fair	3.0	BeO
Anodized Oxide	10^{-4} to 0.002	Good	2.2	BeO
Electroless Nickel	0.0002 to 0.006	Excellent	7.9	92% Ni, 8% P
Electroplating	0.0001 to 0.010	Depends on metal plated	Variable	Metals
Flame Spraying	0.005 to 0.100	Excellent	3 to 17	Oxides and refractory metals

*Angstroms.

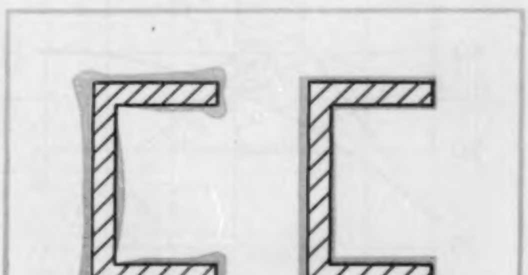

Fig. 3—Comparison of electroplated coating, *a*, and electroless nickel coating, *b*, on beryllium section.

beryllium against severe abrasion and thermal shock because of the composition and thickness of the coat, Table 3. A wide range of refractory compounds can be applied including tungsten carbide, aluminum oxide, and chrome oxide. Any ceramic or refractory material is sprayable if it melts (rather than sublimes) and forms droplets (rather than threads). Several proprietary processes are available for flame spraying of parts.[5]

Surface preparation prior to flame spraying usually consists of a mechanical roughening treatment such as abrasive blasting. In addition, beryllium surfaces must be etched in dilute acid and cleaned with an organic solvent. During flame spraying, the refractory particles strike the roughened surface at a high velocity while still molten and mushroom out to form platelets. A mechanical bond is formed between the refractory and the base material.

Using this technique, refractory materials can be applied to beryllium in thicknesses ranging from 0.005 to 0.100 in. Surface finish of the as-sprayed coat is generally between 100 and 200 mu in. rms. Tungsten carbide has been flame sprayed and diamond ground and lapped to a surface finish of 0.5 mu in. rms.

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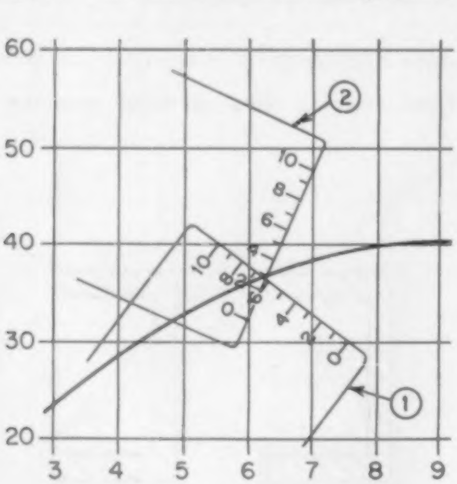
Tips and Techniques

Interpolating Graphs

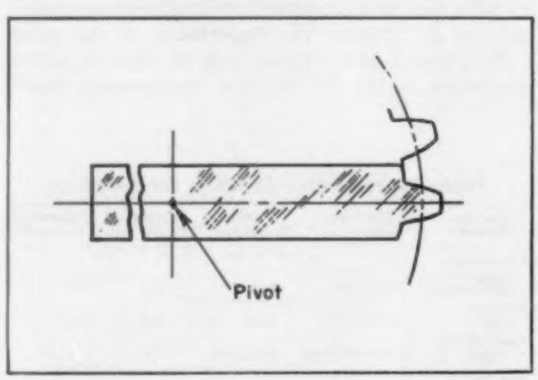
A simple linear scale, such as the one shown in the illustration, can be used to interpolate values on graphs. The scale can be made by drawing ten equal spaces on the edge of a piece of paper or a triangle, so that the total distance is greater than



the space through which interpolation must be made. To illustrate the method: To get the y value on the graph shown, place the scale so that 0 falls on the 30 line, and 10 falls on the 40 line. Then, simply move the scale horizontally until the desired value falls on the scale (36.5). The method is also shown for the x value of the same point (6.33).—Robert F. Peyton, *Ampex Data Products Co., Redwood City, Calif.*

Gear-Tooth Template

Gear teeth can be neatly and quickly drawn with a template made from a strip of plastic. Simply cut the proper tooth shape, scribe a line along the center



of the template, and drill a pivot hole. Allow about 0.010 in. for pencil clearance. Short lines are spaced on the drawing for aligning the template.—Frank Murray, Chicago, Ill.

Charts simplify design of

Cylindrical Pressure Vessels

for full vacuum

R. FENG
Stress Analyst
Worthington Corp.
Harrison, N. J.

MOST pressure vessels intended for external pressurization are designed to withstand a full vacuum internally, and atmospheric pressure externally.

The following charts can be used to quickly find the required wall thickness of cylindrical pressure vessels designed for these conditions. The method is less cumbersome than standard procedures,* and yields exact values.

Procedure: The following example illustrates the simplicity of this method: Determine the minimum required thickness of a cylindrical pressure vessel with D_o = 120 in. and L = 240 in., operating under a full vacuum at 500 F. Material is carbon steel, with yield strength of 35,000 psi.

Find $L/D_o = 2$ on the ordinate of the applicable chart, move horizontally to the intersection with the curve for 500 F (linear interpolation may be used if necessary), then down to $D_o/t = 203$. Calculate $t = D_o/(D_o/t) = 120/203 = 0.59$ in.

Chart Construction: The charts given in this article are for those materials most commonly used. Charts can be constructed, however, for any material and design condition represented in Appendix V of the ASME boiler and pressure-vessel code for unfired pressure vessels.

**Rules for Construction of Unfired Pressure Vessels*, The American Society of Mechanical Engineers, New York, 1959, p. 10.

The form shown in Table 1 may be used to list the necessary values for making a chart. Values shown are for carbon steel with yield strength of 30,000 to 38,000 psi; design temperature to 300 F; P = 15 psi. The following procedure is used:

Table 1—Worksheet for Constructing Charts

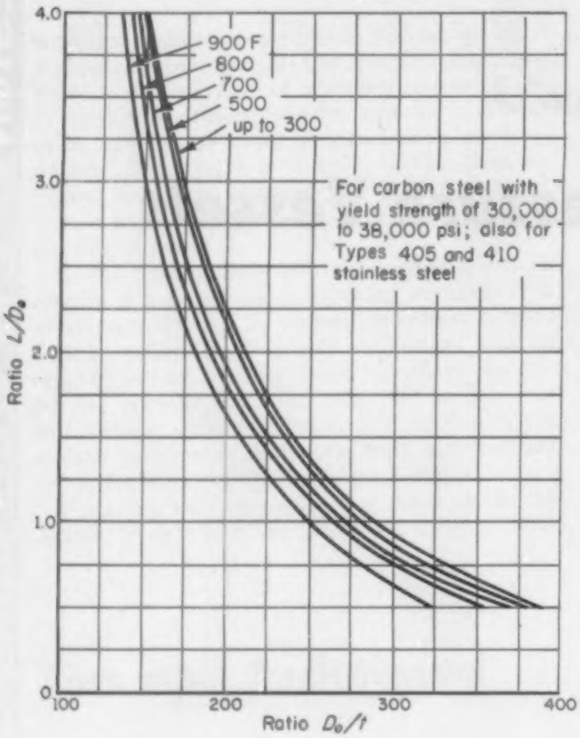
D_o/t	B	L/D_o
500	7500	0.26
450	6750	0.33
400	6000	0.45
350	5250	0.65
300	4500	0.92
250	3750	1.38
225	3375	1.62
200	3000	2.19
175	2625	2.90
150	2250	4.05

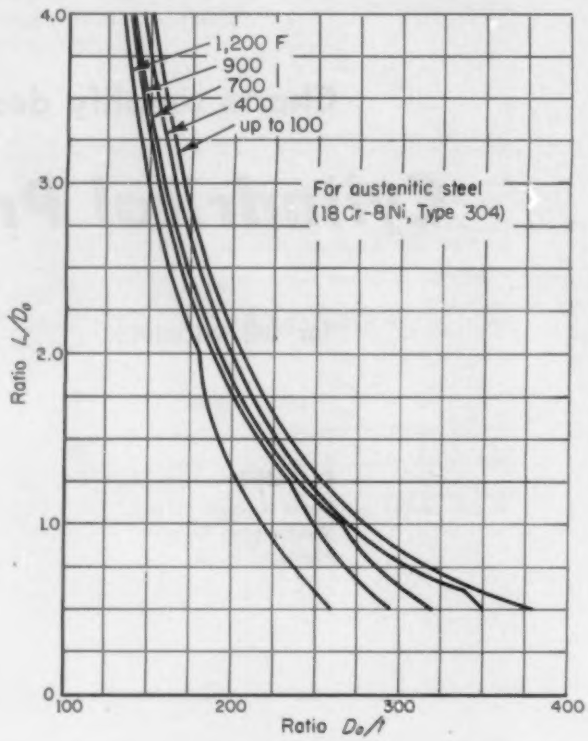
Nomenclature

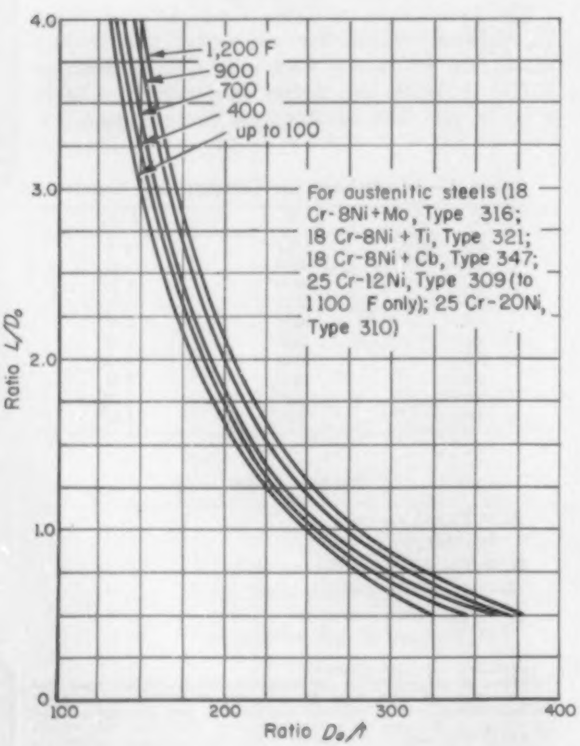
B = Design constant
$= P(D_o/t)$
D_o = Outside shell diameter, in.†
L = Length of pressure vessel, in.§
P = External pressure, psi
t = Thickness of shell material, in.

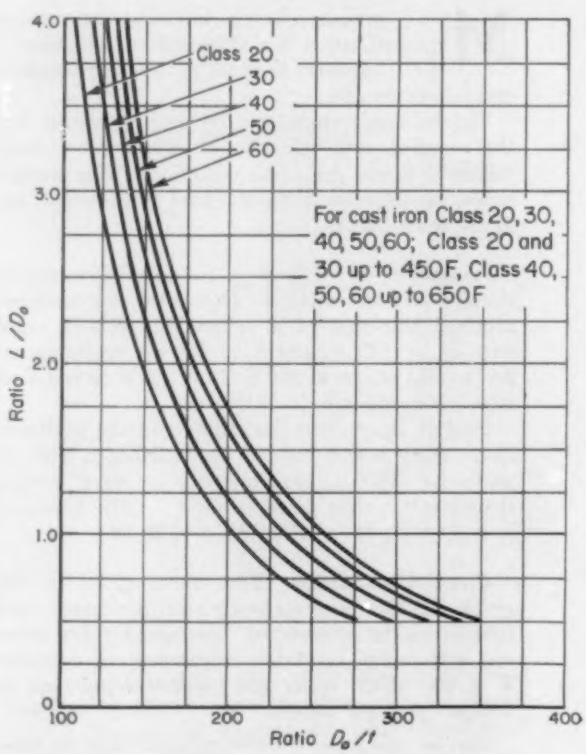
†Excluding corrosion allowance.
§Taken as largest of: 1. Distance between head-bend lines plus 1/3 of depth of each head if there are no stiffening rings. 2. Greatest center-to-center distance between any two adjacent stiffening rings. 3. Distance from center of first stiffening ring to the head-bend line plus 1/3 of head depth, all measured parallel to axis of vessel.

 Circle 26-8 on Page 19 for extra copy.


900 F
800
700
500
up to 300
For carbon steel with yield strength of 30,000 to 38,000 psi; also for Types 405 and 410 stainless steel
Ratio L/D_o
Ratio D_o/t


1,200 F
900
700
400
up to 100
For austenitic steel (18 Cr-8 Ni, Type 304)
Ratio L/D_o
Ratio D_o/t


1,200 F
900
700
400
up to 100
For austenitic steels (18 Cr-8Ni+Mo, Type 316; 18 Cr-8Ni + Ti, Type 321; 18 Cr-8Ni + Cb, Type 347; 25 Cr-12Ni, Type 309 (to 1100 F only); 25 Cr-20Ni, Type 310)
Ratio L/D_o
Ratio D_o/t

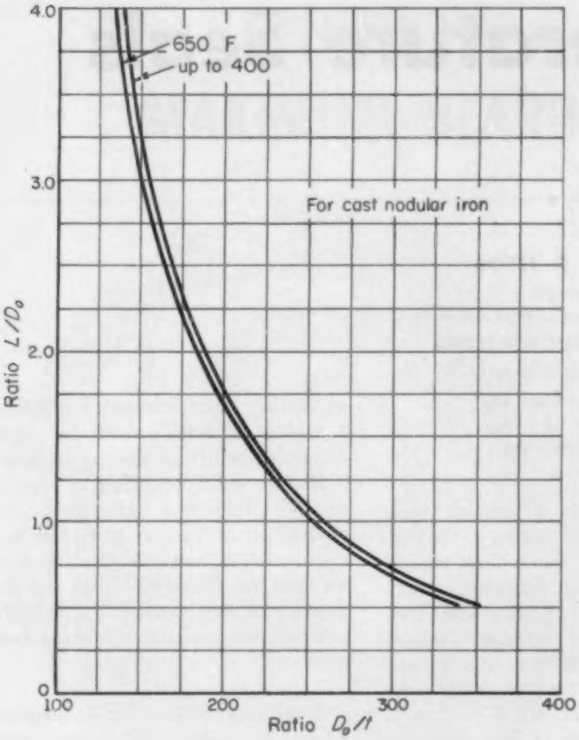

Class 20
30
40
50
60
For cast iron Class 20, 30, 40, 50, 60; Class 20 and 30 up to 450F, Class 40, 50, 60 up to 650F
Ratio L/D_o
Ratio D_o/t

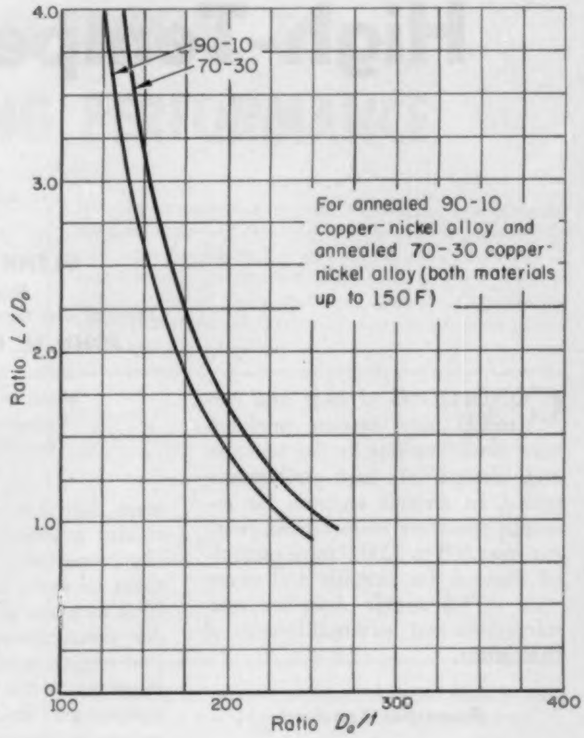
1. For a given pressure, P, and temperature, assume $D_o/t = 500, 450$, etc.

2. Calculate $B = P(D_o/t)$ for various values of D_o/t.

3. For each value of B, find L/D_o from the charts in Appendix V: From B, move left to the intersection of the applicable design-temperature curve; move vertically to the corresponding $D_o/t(K)$; move to the left side of the chart to find L/D_o.

4. Plot the tabulated values.

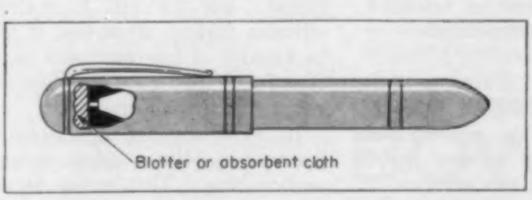




Tips and Techniques

Drafting Pens

Drafting pens, such as the Rapid-O-Graph, often become clogged if allowed to stand idle for too long.



This problem can be solved by placing a piece of oil-soaked blotter or absorbent cloth in the cap, as shown. The oil does not mix with the ink, and will not evaporate quickly. Cotton batting should not be used, since the fibers may stick to the pen point. A drop of oil should be added about once a month.—David P. Sleeper, *Raytheon Co., Wayland, Mass.*

Dividing a Circle

In the November 9, 1961, issue, Page 199, the final paragraph should read: With this method the error in the central angle is less than one min of arc, except for $N = 10, 15$, and 35, where the error is less than 2.25 min.

DESIGN ABSTRACTS

Materials for High-Temperature Seals

GLENN F. HYDE
Manager
Chemical and Metallurgical Laboratory
JOHN H. FUCHSLUGER
Senior Metallurgist
Metal Products Div.
Koppers Co., Inc.
Baltimore, Md.

CONDITIONS of heat and corrosion have become predominant considerations in the selection and design of high-performance seals. In aircraft engines, for example, operating temperatures ranging from 600 to 1200 F have prompted research for suitable seal materials. This article describes considerations and accomplishments of that effort.

Properties Required

Corrosion Resistance: In aircraft engines, a sealing ring is subjected to high temperatures and corrosive gases. These conditions are aggravated by the fact that the engines generate a heating and cooling cycle. The sealing ring is first subjected to extreme heat from hot gases. This is followed by a soaking-type heat which is imparted to the ring from heat absorbed by the larger metallic parts of the engine. Then a cooling cycle follows, during which the temperature of the system may fall below the dew point of the surrounding atmosphere. Moisture formed as a result of condensation, in combination with residues from products of combustion, produces corrosive acids.

Flexibility: A piston ring or sealing ring, besides serving its primary function as a metallic seal, is also a metallic spring. Spring-like properties of these rings enable them to exert the necessary radial force to make an effective seal. Under conventional internal-combustion engine conditions, engine heat imparted to the ring generally does not exceed about 400 F. This is primarily because of the elaborate means of cooling. The sealing rings in many parts of an aircraft power plant, however, may be subjected to temperatures as high as 1200 F, and sometimes higher. To maintain effective spring-like qualities under these conditions of heat, rings must possess a high degree of resistance to stress relaxation, that is, good "heat stability." Heat stability is the capability of a piston ring to maintain its free gap and diametric tension after having been subjected to high temperatures in a closed position over an extended period of time at temperature.

Wear Resistance: Piston or sealing-ring material designed to operate under conditions of elevated temperatures must possess good wear properties in the absence of conventional lubricants. Good wearing materials must be considered as mating pairs because a material is seldom, if ever, universally good-wearing against all mating surfaces.

Besides solid materials, a considerable effort has gone into the evaluation of various wear-resistant coatings. A suitable coating may be used to effectively offset the deficiency of poor wear of a good high-temperature corrosion-resistant base material.

Conformability: This property of piston rings and sealing rings is related both to the design of the ring and also to the elastic modulus of the material from which the ring is made. Conformability relates to the ability of the sealing ring to conform to the shape of the cylinder in the case of a piston-ring-type seal, or to the shape of a rod if the application is a contracting-type sealing ring. Conformability is important because the cylinders and rods in engines subjected to even moderately low operating temperatures do not remain absolutely round. For the seal to maintain effective sealing properties, it must be capable of following any out-of-roundness that may develop as a result of thermal stresses.

In most engines, a differential-pressure condition exists across a sealing ring. This is the primary reason for the sealing element being employed. Pressure developed

Circle 26-9 on Page 19 for extra copy.

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TEAR OUT AND PUNCH AS INDICATED FOR YOUR FILE

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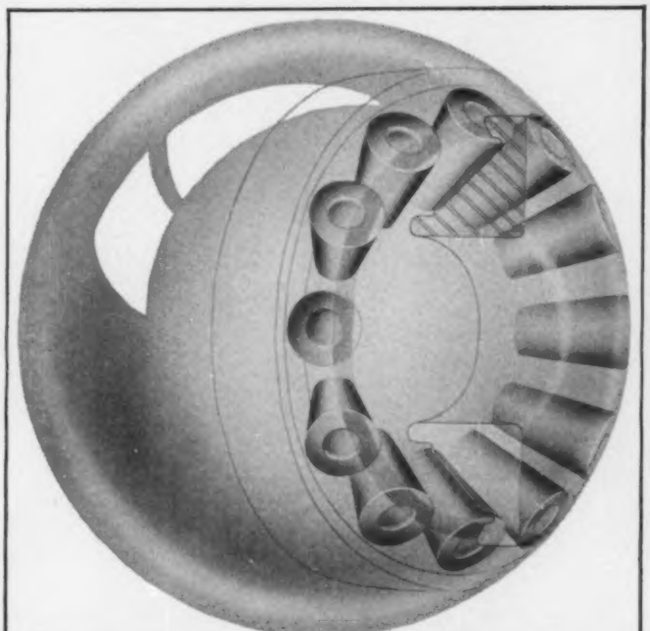
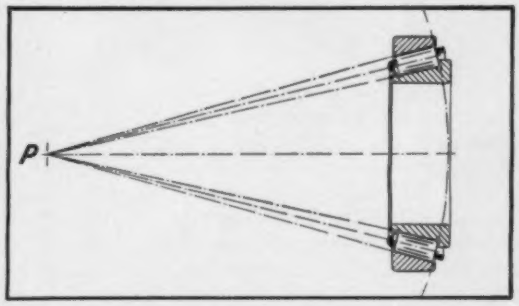
BEARING BRIEFINGS

SPHERICITY—ESSENTIAL TO MAXIMUM BEARING PERFORMANCE



When you require bearings, we suggest you consider the advantages of Bower bearings. Where product design calls for tapered or cylindrical roller bearings or journal roller assemblies, Bower can provide them in a full range of types and sizes. Bower engineers are always available, should you desire assistance or advice on bearing applications.



True rolling of tapered bearing elements depends upon maintaining a true spherical radius during manufacture.

For a tapered roller bearing to achieve maximum performance, i.e., maximum life and capacity under load, it must have true sphericity — a condition of bearing geometry which permits true rolling of the tapered rollers in the raceway.

True rolling in tapered bearing elements is the result of maintaining a critical geometric relationship between the raceways and the contact surfaces of each roller. True rolling is essential to maximum performance. Without it, premature bearing failure is certain.

As engineers know, a tapered roller will describe a true circle when rolled on a plane surface. *It will always roll in this one path precisely, without sliding or skewing*. But to put true rolling to work in a bearing which can carry both heavy thrust and radial loads, it is essential that the rollers *and* the raceway have a true spherical radius, or sphericity. The drawing illustrates this condition.

If each roller in the bearing were to be extended in length, while retaining its taper, it would form a cone, terminating at point "P". All cones generated from all rollers would meet at point "P", which is also the center of the hypothetical sphere shown. The surface of the sphere would *touch all points on each roller's head!*

In effect, then, each roller's taper determines the radius of a hypothetical sphere whose surface, in turn, determines the correct contour for each roller head. Only when these conditions are satisfied in design, and when they are rigidly held during manufacture, will true rolling take place. In the manufacture of each Bower tapered roller bearing, sphericity is held within extremely narrow limits by means of special Bower-designed precision grinders. The consistent accuracy possible with these machines is one major reason why Bower roller bearings provide maximum performance under all speeds and loads up to the bearing's maximum rating.

BOWER ROLLER BEARINGS

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Circle 274 on Page 19

Table 1—Wear Ratings of Solid Materials Against Typical Mating Surfaces at Room and Elevated Temperatures

Material	Maximum Service Temp of Oxidizing Atmosphere (F)	Room Temp Wear Rating/1000 F Wear Rating*: CrC	TiC	WC	Cr-Al_2O_3	Cr-Mo-Al_2O_3	Al_2O_3	Cr Plate	Cr-Ni-W-Co-"B"	Cr-C-Fe-"B"	Nit. Nit. 135 M	AISI 410	AISI 440 F	17-4 PH	AISI T-15	AISI M-3 Type 1
Impregnated Carbons:																
Carbon A	1100				F	G		G	G	G/G		F/F				
Carbon B	1200				G	G		G	F	G		F		F		
Carbon C	1300		G				G		G	G				P	G	
Carbides, Borides, Nitrides, and Intermetallics:																
TiC	1100	G/G	G/G				G/G	P	P	F/G	F		P			
CrC	1300	G	G/G	G			G/P	P	F		F	P		P	G/G	F
WC	900		G/G	G/G			G/G	P	P	G	G	P	F	G/G	G	G/P
$MoSi_2$	1300	G/G	P			F	G		P	F						
SiNi	1300	G/G	G				G		F	P						
TiB—CrB	1200	G	F		P		G/G		P	G						
Ceramics:																
Al_2O_3	>1300	G/G	G	G/G		P	G/G		P	P	F					
High Temperature Alloys:																
Cr-Ni-W-Co-"A"	>1000	G/F			P		G/G		P							
Cr-Ni-W-Co-"B"	>1000	G/G	G/G	G/G	P	P	G/G	P	P	P	F	P			G/G	F
Irons and Steels:																
AISI T-15	1000	G	G/G	G/G			G	G	F	P	F	P	P		G/G	G
C-V Die Steel	900		G				G	G	F						G	
AISI H-12	1000		G	G			F	F	F				P	P	F	
AISI 440 F	1000		G	G/G			G/F	P	F	P			P	P	G/G	
440 Modified	1000		G/G				G	G	G/P	P				P	G	

* G = Good, F = Fair, P = Poor

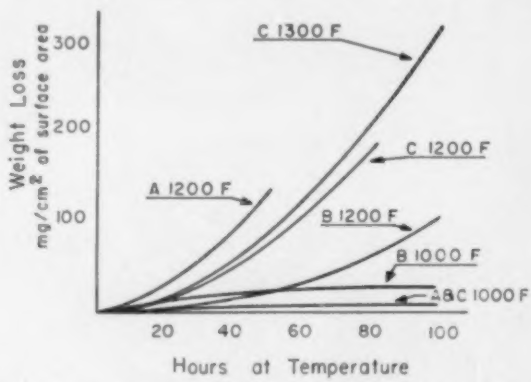

Fig. 1—Oxidation rates of three carbon materials, A, B, and C.

in the system is beneficial because it acts on the inside surfaces of a piston-ring-type seal to force the ring against the cylinder and one side of the ring groove, thereby preventing leakage. In a shaft-type seal, the pressure acts on the outside diameter of the ring and the ring retaining groove, thereby effecting a seal between the rotating shaft and the ring ID as one sealing surface, and the ring groove and the side of ring as the second sealing surface.

With a high pressure differential, materials having high elastic moduli may be employed. When the pressure differential is low, materials having low elastic moduli must be used. Sealing ring moduli in high-pressure systems, such as diesel engines, may run as high as 20 to 30 million psi where malleable irons and steel are employed.

Conformability is less significant where the seal is a face-bearing type. In such instances one flat side of a ring bears against another flat surface and the seal is effected primarily on these mating surfaces.

Many promising materials possess very high elastic moduli on the order of 40 to 50 million psi. High elastic modulus limits seal design to the face-bearing type.

Economics: Many of the new piston-ring and sealing-ring materials are promising functionally but too expensive to make. This is particularly true of many of the high-temperature alloys, and oxide and carbide type materials.

In the field of coatings, many require the purchase of expensive new equipment, or are proprietary, requiring licenses and the payment of royalty fees.

Types of Wear

Principal types of wear are: 1. Adhesive (galling). 2. Abrasive (cutting). 3. Corrosive. 4. Surface fatigue.

All of these types of wear have been given extensive coverage in the literature. It seems noteworthy to state, however, that elevated temperatures greatly accelerate the first three types.

Tests on SAE 4140 steel have shown wear rates 2½ times greater at 450 F than at 300 F under otherwise identical conditions. Unless mating parts are designed specifically for high-temperature wear, the wear rate will increase by an exponential factor as temperature becomes higher.

Metallic elements which possess a high degree of solubility in each other are much more susceptible to adhesive types of wear than metallic elements possessing low solubility. It is logical to expect the solubility factor and related adhesive wear to accelerate at elevated temperatures because the ambient temperature approaches welding temperature.

Circle 275 on Page 19→

It's more than a matter of taste

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Table 2—Room Temperature Wear Ratings and Friction Coefficients of Piston Ring Coatings Against Typical Mating Surfaces

Coating Description	Max Service Temperature Oxidizing Atmosphere (F)	Room Temp Wear Rating*—Coefficient of Friction: T-15 Tool Steel		17-4 PH Stainless		Cast Iron BHN 201		Cast Iron BHN 432		Anodized Aluminum		Hard Cr Plate	
Hard Metal Coatings:													
Cr Electroplate	700	G	.30	P	.37	F	.42	F	.42	P	..	..	..
Sprayed Mo	700	G	.52	P	.35	G	.55	G	.63	P	..	F	.45
Co-Ni Electroplate A	800	F	.40	P	.45	F	.42	F	.45	P	..	..	..
Co-Ni Electroplate B	800	G	.45	P	.40	F	.34	F	.28	P	..	..	..
Ni Chem. Plated	900	P	.27	P	.50	P	.46	P	.35	P	..	..	..
Fe Electroplate	700	G	.47	P	.31	F	.40	G	.47	..	..	G	.58
Carbide and Oxide Coatings:													
85 Cr_3C_2—15 Ni-Cr	1300	G	.39	P	.30	G	.51	F	.57	P	..	..	..
WC—7 Co	1000	G	.33	F	.35	G	.44	G	.36	P	..	..	..
25 WC—7 Ni-68 WCrC	1200	G	.67	F	.64	G	.76	G	.64	P	..	..	..
WC—12 Co	1000	G	.34	P	.40	G	.42	G	.33	..	..	..	..
80 WC—20 Binder	800	G	.35	P	.40	G	.65	G	.50	..	..	P	.35
Al_2O_3	>1300	G	.51	F	.35	G	.47	G	.60	..	..	..	..
Solid Lubricant Type Coatings:													
Graphite + MoS_2 + Resin	800	G	.29	F	.18	G	.20	G	.20	F	.45	G	.29
W + MoS_2	600	G	.08	G	.06	G	.09	G	.08	G	.07	G	.11
MoS_2 + Resin	600	G	.13	G	.14	G	.12	G	.14	G	.18	G	.15
MoS_2 + Graphited Pb Powder	700	G	.14	G	.16	G	.15	G	.14	..	..	G	.16
MoS_2 Formulation	800	G	.21	G	.11	G	.14	G	.15	..	..	G	.18
Soft Metal Coatings:													
Ag Electroplate	600	G	.43	F	.70	F	.65	F	.65	P	..	..	..
Sn Electroplate	600	F	..	F	..	P	..	F	..	..	..	..	..
Diffused Cd-Ni Electroplate	800	F	.45	F	.40	F	.32	F	.45	P	..	P	..
Surface Treatments:													
Steam Trmnt. (Cast Iron)	800	P	.35	F	.50	F	.56	F	.54	..	..	P	.57
Malcomized 17-4 PH	900	F	.35	P	.42	F	.55	F	.45	P	..	..	..
Phosphated (Cast Iron)	600	..	..	..	..	G	.49	G	.58	..	..	..	..
Sulfurized (Cast Iron)	1000	..	..	..	..	F	.55	F	..	..	..	..	..
Nitrided Nitralloy 135M	1000	..	..	..	..	P	..	..	..	..	..	F	..

*G = Good, F = Fair, P = Poor

Because of the formation of metallic oxides, abrasive or cutting types of wear would also be a more predominant factor at elevated temperatures.

Types of Materials

The materials investigated fell into the following categories: Carbons (compounded and bonded electro-graphites, sometimes impregnated); carbides, nitrides, borides, and intermetallics; ceramics and cermets; irons and steels; high-temperature alloys; hard-facing alloys; surface treatments and coatings. The categories of surface treatments and coatings are important in themselves because they represent a method of adding good wear properties to materials that are desirable in all other respects but are inherently poor wearing. Also, many good wearing materials that are available as surface coatings are prohibitive in cost and extremely difficult to fabricate as solid bodies.

Properties of Solid Materials

Due to the large number of materials evaluated, only typical wear results obtained with the more promising materials are cited, Table 1.

Carbons: Most unimpregnated carbons disintegrated completely or deteriorated rapidly at temperatures of 1000 F. The impregnants developed in recent years, however, gave extended life at 1000 F to a number of carbons, and a few even show appreciable life at 1200 F and at 1300 F. This is illustrated by oxidation curves, Fig. 1, for three representative impregnated carbons. In Table 1, impregnants do not appear to impair the excellent wear properties normally associated with these materials.

Table 3—Compatibility Ratings of Dry and Lubricated Brakeshoe Type Wear Tests

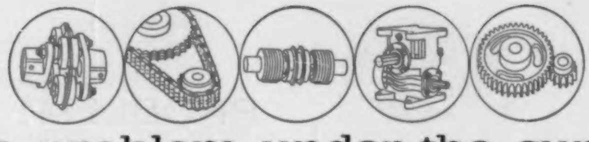
Rider Material[1]	Compatibility Ratings[3]: Dry[2]	MLO 8200	Versilube	Poor	Poor	Poor	Poor	81717	Polyester
Flame Plated WC	Good	Poor	Poor	81644	WRGL 31A	Pentalube	XF 258	Poor	Poor
T-15 Tool Steel	Good	Good	Good	Good	Good	Good	Good	Good	Good
Solid TiC	Fair	Fair	Good	Good	Fair	Good	Fair	Fair	Poor
T-4 Tool Steel	Good	Fair	....	....	....	....	....	....	....
Cr-Ni-W-Co	Good	Fair	....	....	....	....	....	....	....
Carbon	Good	Good	....	....	....	....	....	....	....
Impregnated Carbon	Good	Good	....	....	....	....	....	....	....

[1]Ring material: Flame plated WC (tungsten-carbide) in all tests.
[2]Dry tests run 1 hour, lubricated tests 5 hours.
[3]See accompanying table for lubricant data.

Synthetic Lubricant Data

Lubricant	Type	Operating Range
Versilube F-50	Silicone with chloro-phenyl groups	−100 F to +450 F. Can be used at 700 F for short periods with the exclusion of air.
81644	Silicone with Anti-oxidant additive	−100 F to +510 F.
81717	Silicone with Poly-meric additive	−100 F to +600 F. Operation at 700 F under special conditions.

Lubricant	Type	Operating Range
MLO 8200	Disiloxane (special type of silicate ester)	Extended use at temperatures above 400 F.
WRGL-31A	Hydraulic fluid	Not available.
Pentalube TP-653	Neopentyl polyol ester with 1% PANA & 1% 5-10-10	−65 F to 400 F.
Polyester	Anderol polyester hydraulic fluid	Not available.
XF 258	Silicone	Not available.



Morse has an answer to every industrial drive problem under the sun

From oil rigs, boats, and cars to missiles, mowers and machinery—look first to Morse for transmission of motion or power. You'll get impartial engineering help and immediate delivery on a complete range of products: Basic Drives, Speed Reducers, Couplings, and Clutches. Basic Drives alone include stockgears, roller chain, silent chain, "Timing"® Belt, and Hy-Vo® Drives. You'll find your Morse man in the Yellow Pages. Or write: Morse Chain Co., Dept. 6-121, Ithaca, Ithaca, N. Y. Export: Borg-Warner International, Chicago 3, Ill. In Canada: Morse Chain of Canada, Ltd., Simcoe, Ont.

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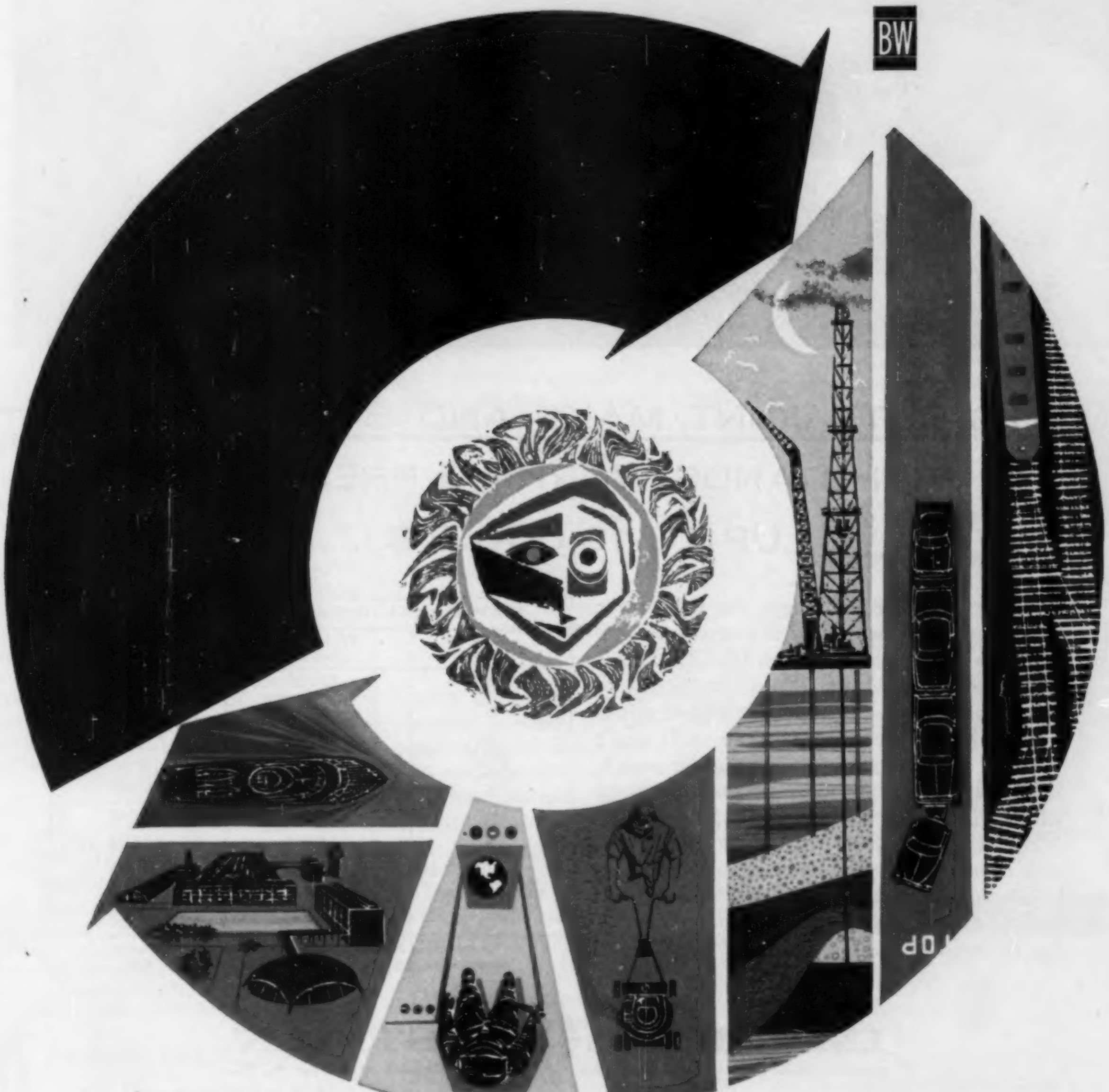
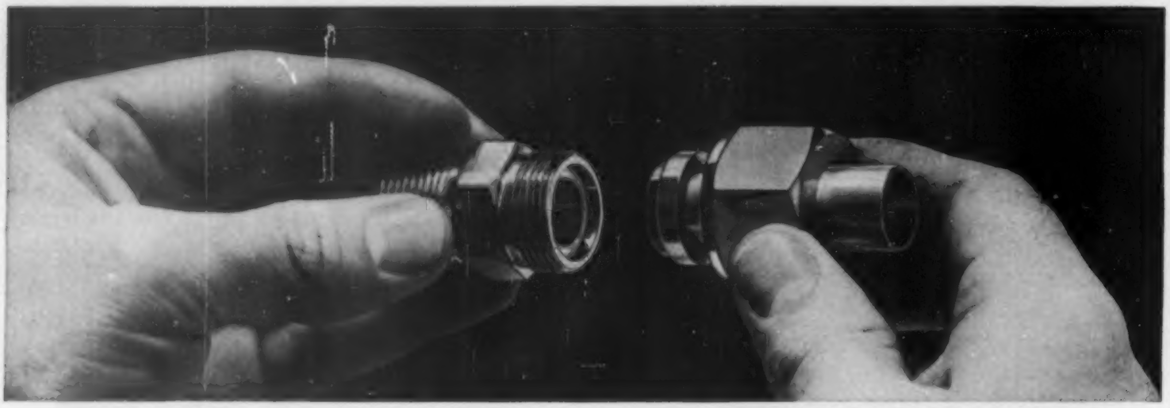


Circle 276 on Page 19

PROBLEM: absolute reliability of a weldless tube fitting under super pressures, high temperatures, high-frequency vibration or shock

SOLUTION: BRAZE-SEAL



THIS BUTT-JOINT, MAKE-AND-BREAK FITTING WITHSTANDS WORKING PRESSURES UP TO 19,000 P.S.I.*

On many installations where you think only a more costly welded tube fitting can do the job, this Imperial butt-joint BRAZE-SEAL fitting now takes over. It's a compact, economical, simple-to-install fitting withstanding *super* working pressures (see table). It won't yield to high-frequency vibration or shock. With special brazing alloy rings, this fitting withstands temperatures up to 1500° F.

Because Braze-Seal fittings are not welded, you retain the convenience of a make-and-break joint. For more details, call your nearby Imperial-Eastman distributor—or write for Bulletin 3120.

MAXIMUM DESIGN PRESSURES FOR BRAZE-SEAL FITTINGS

Tube O.D.	P.S.I.—316 Stainless	P.S.I.—Carbon Steel
¼"	77,000	60,000
⅜"	64,000	48,000
½"	62,400	46,800
9/16"	61,600	—
⅝"	61,600	46,200
¾"	60,000	45,000
⅞"	56,000	42,000
1"	52,000	39,000
1¼"	48,000	36,000
1½"	44,000	33,000

*Recommended working pressures allow for 4-to-1 safety factor on sizes up to ¾" O.D.; 6-to-1 on sizes ¾" to 1½" O.D.

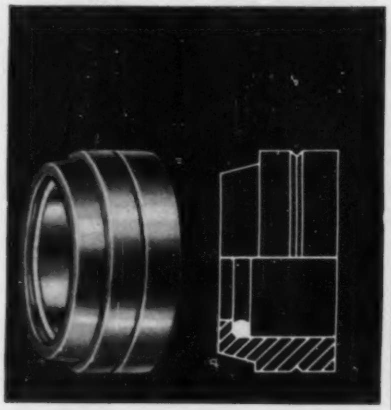
IMPERIAL EASTMAN

Imperial-Eastman Corporation General Offices: 6300 West Howard Street, Chicago 48, Illinois

Imperial-Eastman Corporation (Canada) Ltd., Barrie, Ontario • Imperial-Eastman, S.A., Apartado Postal 26544, Mexico 13, D.F.

Circle 277 on Page 19

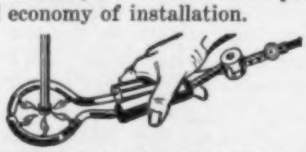
FITTINGS



secret of superiority— silver alloy brazing ring

Inside the Braze-Seal fitting sleeve is a brazing ring of silver alloy. When the sleeve is slipped over the tube end and heated, the alloy forms a tough, lasting bond between the tube and sleeve. After brazing, the fitting is easily assembled —no special machining necessary, no special tubing required, no flaring, no danger of "over-torquing" the fitting because you can see when it's tight.

Braze-Seal fittings offer other Hi-Seal fitting advantages: make-and-break convenience, close bends made possible, and economy of installation.



6-FLAME TORCH SPEEDS BRAZING
This Braze-Seal acetylene torch simplifies the making of brazed joints. Six-flame jet on circular tip heats sleeve evenly—quickly brazes the silver alloy to form a super-pressure-tight seal.

IMPERIAL — EASTMAN

Carbides, Nitrides, Borides, and Intermetallics: All of these materials resisted oxidation well at 1000 F. As a class they are relatively good wearing. The metal carbides in particular show exceptionally good wear properties.

Ceramics and Cermets: All of the ceramics and cermets successfully withstood the oxidation test. These materials, too, are capable of withstanding temperatures considerably above 1000 F. The cermets and most ceramics show high friction and tend to score their mating surface. Aluminum oxide is one of the better wearing ceramics.

High Temperature Alloys: Most high-temperature alloys have excellent strength and oxidation resistance at 1000 F, but relatively poor wear properties. Only two alloys showed "fair" to "good" wear properties.

Irons and Steels: The best wearing of the irons and steels are those containing carbides. Type 440 stainless steels and the tool steels, all of which have high carbide content, have relatively good wear resistance against a variety of mating surfaces. The oxidation resistance of these materials, however, is not the best. The more oxidation-resistant steels, such as 300-series stainless, have very poor wear properties.

Platings, Coatings, and Surface Treatments

A coating may be selected to combat any type of wear whether abrasive, adhesive, corrosive, or a combination of these causes. Surface coatings also enable selection of a base material which satisfies one requirement and a coating material which satisfies the wear requirement.

Coatings for high-temperature wearing parts can be classified according to performance and to methods used to obtain the coatings:

1. Wear-resistant coatings
   a. Hard metal deposits
   b. Carbide and oxide-type coatings
2. Break-in type coatings
   a. Compositions containing solid lubricants

A Morse answer

Torque limiters

...when the problem involves automatic overload protection

Protect expensive equipment

Eliminate shear pins

Lessen costly downtime

Adaptable to any drive

Easily adjusted

Controlled torque setting

Capacities: 10 to 6300 ft.-lbs.

Clutch sizes: 3 to 20 inches

Distributor-stocked

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Circle 278 on Page 19

. . . the 1st High Quality Appliance Switches in the 10¢ Range

- **Cost-Saving Construction** in the 10¢ range for quantity users. Added savings in mounting and wiring.
- **Space-Saving, Low Profile Design** only 31/64" mounting depth. Leads exit from ends, not bottom. Fits compact handles where others can't — in cleaners, polishers, projectors, power tools, hair dryers, and others.
- **Time-Saving Installation.** Quick-connect terminals accept AMP "Faston" or similar insulated or non-insulated receptacles.
- **Nyon-Insulated Terminals** with molded-in creepage barriers. Need no supplementary insulation. Snap-on nylon terminal shield (optional) completely covers "live" parts.
- **6-Ampere Rating** at 125 volts ac. U.L.I. inspected. SP-ST or SP-DT circuits.
- **Durable, Attractive** with smooth "feel" and positive detents. Molded trigger knobs in three standard lengths and in colors for modern styling.

Write for details on Types SS-37 and SS-37-1 from the world's largest slide switch manufacturer . . . **Electronic Components Division, Stackpole Carbon Company, St. Marys, Pa.**

STACKPOLE

BRUSHES FOR ALL ROTATING ELECTRICAL EQUIPMENT • CERAMAGNET® CERAMIC PERMANENT MAGNETS • ELECTRICAL CONTACTS • FIXED & VARIABLE COMPOSITION RESISTORS • SNAP & SLIDE SWITCHES • FERRITE CORES • GRAPHITE BEARINGS & SEAL RINGS • GRAPHITE HEATING ELEMENTS & ELECTRODES • HUNDREDS OF RELATED CARBON & GRAPHITE PRODUCTS

b. Soft-metal deposits

3. Both wear-resistant and break-in types
   a. Hard or soft coatings created by thermal diffusion or chemical reaction with the base materials

Results of performance tests on these classes of coatings are summarized in Table 2. The most promising coatings for elevated-temperature service are the wear-resistant types. However, the hard metal deposits, which include hard chromium plate, are not always considered good for elevated-temperature wear. Chromium plate softens rapidly when subjected to heat, and the softening promotes adhesive-type wear. For example, electrochemically plated chromium in as-plated condition possesses a hardness on the order of Knoop 950 to 1100 (850-950 Bhn). The hardness may be lowered to Knoop 550 (496 Bhn) by heating to 1220 F. Other hard-metal coatings have not shown exceptional promise functionally. Another disadvantage is the difficulty of applying them to piston-ring and sealing-ring configurations. Application frequently results in altering of the metallurgical structure of the base materials or excessive distortion of the coated part.

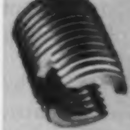
The carbide and oxide coatings hold exceptional promise for elevated-temperature piston-ring and sealing-ring applications. These materials, as a general rule, have "good" dry-wear properties against mating surfaces of hardened tool steel, and medium-hardness and high-hardness cast irons. This indicates that these materials resist welding. Or, if welding occurs, it is a covalent bond—brittle and friable. The metallic oxides and carbides possess metallurgical stability in the temperature range of 1000 to 1200 F, and at higher temperatures for certain coatings such as aluminum oxide. That is, they retain their hardness which varies from DPH 1000 to 1450.

Solid Lubricant Coatings: Almost all of the solid-lubricant type coatings are formulations containing molybdenum disulphide as the primary constituent. Various liquid carriers also serve as bonding agents

 Circle 279 on Page 19

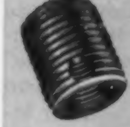
The quickest most practical way to put strong threads in soft materials

the TAP-LOK® INSERT



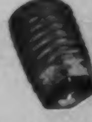
SLOTTED

IN SOFTER METALS AND PLASTICS... Has full V-form external threads to provide maximum locking torque and permit wide choice of mating hole sizes. Recommended for soft aluminum, zinc die castings, sand castings and plastics. Meets requirements of MIL-MS-35914.



H-SERIES

FOR HIGHER STRENGTH MATERIALS... Has heavy wall and truncated root external thread and three-hole cutting edges for hard-to-tap higher-strength materials and to meet MIL and other specs calling for Class 3B thread fit for gaging after installation.



F-SERIES

ELIMINATES CHIPS... The F-Series Form-Lok self-tapping insert is thread forming and firmly locks itself in the base material. Available from stock in sizes #4 through %".

W-SERIES

FOR WOOD... Has coarse pitch external threads offering maximum strength in combination with ability to be driven into thin sections without splitting them. For furniture, cabinets and other wooden parts where strong, permanent threads are needed, or that are frequently assembled and disassembled.

SEE OUR CATALOG IN SWEET'S

Another fastener development from—

TAP-LOK / GROOV-PIN CORPORATION

1130 Hendricks Causeway, Ridgefield, N. J.

Circle 280 on Page 19

after the coatings have dried. Some of the higher temperature coatings of this type have metallic additions such as tungsten. These additions, plus a high temperature binder, enable them to be used at higher temperatures. The authors' tests show, however, that molybdenum disulphide converts to a tri-oxide at temperatures on the order of 1000 F. The tri-oxide is very abrasive, hence catastrophic to wear. As a general rule, the molybdenum disulphide formulations are applied over a chemically etched base metal such as a phosphating treatment used for cast iron and steel.

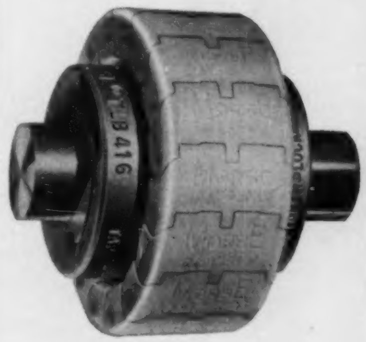
These coatings, for the most part, are classified as break-in types. They establish a compatible wearing surface, but they cannot be expected to be permanent.

Chemical Conversion Coatings: Two methods presently being used for creating break-in type coatings by chemical conversion of the base metal are: 1. Steam treatment, which creates an iron oxide coating. 2. Immersion of ferrous parts in a manganese-iron phosphate solution, which forms a black iron-phosphide-type coating. Both of these coatings are very thin—0.0001 to 0.001 in. Their main advantage is that they provide a certain amount of corrosion resistance. Chemical conversion of the base material creates a matte-like surface which holds oil or improves adhesion of the solid-film lubricant-type coatings.

Dry vs. Lubricated Operation: If wear properties are good under conditions of no-lubrication, does a lubricant make wear properties better? To find answers, former dry combinations were tested with eight different synthetic lubricants.

The results of these tests, Table 3, suggest that wearing pairs, which show "good" results when tested dry and "poor" results when tested under lubricants, are creating a dry film lubricant, which is a by-product of wear, as they rub together in an atmosphere of air. When the air atmosphere is excluded, as it is when the lubricants are used, the dry film lubricant cannot form, and scuffing ensues. Additional research is suggested in this area.

A Morse answer



Nylon couplings

...when the problem involves corrosion, cost, lubrication

- Corrosion-resistant
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- Safety first
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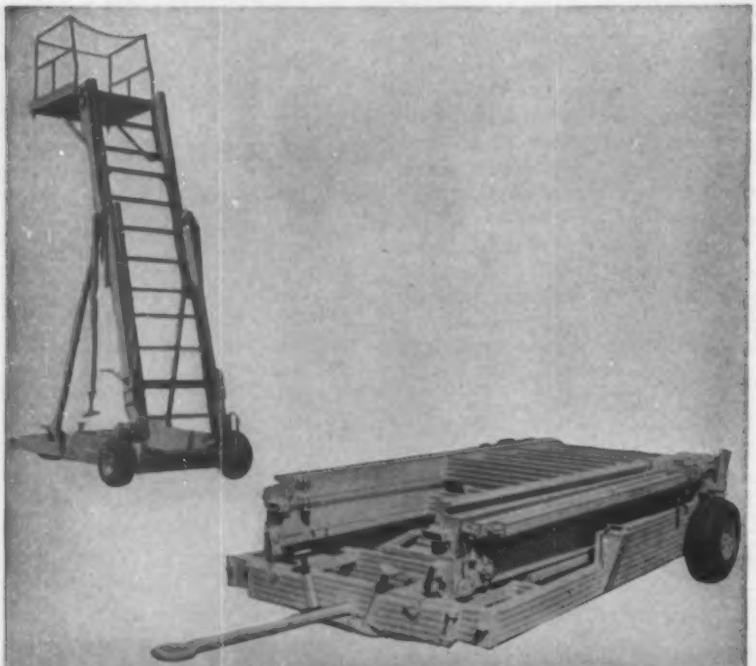
LUBRICATION REPORT

(TFE coating)



Application: *Portable Aircraft Maintenance Stand Lubrication.*

Problem: *To Minimize sliding friction at widely varying temperatures.*

Solution: *EMRALON® 310 (a tetrafluoroethylene pigmented, bonded film lubricant)—spray-applied and baked at 300 F for one hour.*

RESULT: *ALL-WEATHER COATING GIVES TELESCOPING STAND NEEDED LOW-FRICTION SLIDING SURFACES*

This lightweight portable aircraft maintenance stand was developed for use by the U. S. military forces by South River Metal Products Co., Inc., of South River, N. J. Approximately 40 lineal feet of telescoping surfaces are contained in the stand which elevates to 13 feet for use, and compacts to a height of only 2 feet for transporting. Tests showed that the sliding magnesium sections were readily subject to galling and seizure. The dry-film coating obtained with Acheson's 'EMRALON' 310 provides the necessary lubrication through an ambient range from desert heat to Arctic sub-zero temperatures . . . and does not cake, evaporate or freeze.

Perhaps one of Acheson's series of TFE coatings can help solve your dry-film lubricating problem. Write for 'EMRALON' 310 or 'EMRALON' 320 (air dry) Product Data Sheets. Dept. MD-121.

ACHESON– First name in solid lubricants for fifty-four years.

ACHESON *Colloids Company*

PORT HURON, MICHIGAN

A division of Acheson Industries, Inc.

Sales offices in principal cities

Also Acheson Industries (Europe) Ltd. and affiliates. London, England

ASLE Preprint No. 61 AM 1B-1, "Materials for Elevated Temperature Piston Ring and Seal Ring Applications (600 F to 1200 F)," presented at the 16th ASLE Annual Meeting, Philadelphia, April, 1961, 19 pp.

techniques

Digital Telemetering Techniques

A. Brothman, E. H. Brothman, students, Barnard College, Columbia University, and R. D. Reiser, Engineering Dept., Electronics Div., Industrial Process Engineers Inc.

A state-of-the-art report of the subject, including definitions, system design concepts, and comparison with analog techniques.

Digital telemetering is favored by a greater intrinsic accuracy capability, a direct suitability to data logging, a direct suitability to computer control, and—in many instances—a higher information rate.

On the debit side for digital telemetering, there is a higher equipment cost, a tendency in some instances to include "process noise" as an additive or subtractive factor to the mean value of the meter information in spot or individual readings, and a greater complexity in imposing alarm and drift monitors at the receiving end of the system.

"Digital Telemetering Techniques," presented at the National Telemetering Conference, Chicago, May, 1961, Conference Proceedings pp. 2-13- to 2-36.

hydraulic

Partial Flow Centrifugal Compressors

N. Van Le, Airesearch Mfg. Co., Los Angeles, Calif.

Results of an exploratory investigation on partial-flow centrifugal compressors.

Experimentally, partial flow obtained from an existing compressor shows that the best results were obtained by simply blocking the guide vane diffuser. The penalty is neither severe nor too light. At a partial flow of 50 per cent, the peak efficiency is reduced by 25 per cent.

At lower fractions of partial flow, the fluid bounces back and forth in

Circle 282 on Page 19

HASTINGS Instruments

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VACUUM, FLOW, PRESSURE and AIR VELOCITY

Hastings instruments, operating on the tried and proven principle of the Hastings Patented Thermopile, offer sensitive, accurate readings with almost instantaneous response. Long instrument life and low maintenance costs are assured since there are no electronic or ballast tubes to burn out, break or fail. The electrical output of the thermopile makes a Hastings instrument ideal for remote indication, control, and recording.

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Gauges, Controllers and Recorders are available in over 100 models to cover pressure ranges from .2 micron to 200 mm Hg. Choice of single or multi-position instruments, cabinet or panel-mounted. For full details, send for Catalog No. 300.

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WRITE FOR FULL INFORMATION ON OUR COMPLETE LINE OF HASTINGS INSTRUMENTS. IF YOU HAVE ANY APPLICATION PROBLEMS, OUR ENGINEERING STAFF WILL BE GLAD TO ASSIST YOU.

HASTINGS-RAYDIST, Inc.

Hampton, Virginia PArk 3-6531

Circle 283 on Page 19

the impeller passages associated with the closed fraction of the diffuser. This back flow is thought to be a great source of penalty in performance.

Theoretical investigation brings out the sources of penalty in operation at partial flow. On a relative basis, it is shown that a radial flow configuration gives a better performance than a backward bend compressor. Also, the idea of a large number of blades approaching the design of good partial admission turbine is found to be valid for partial flow compressors.

ASME Paper No. 61-WA-135, "Partial Flow Centrifugal Compressors," presented at the Winter Annual Meeting, New York, November-December, 1961, 12 pp.

Performance of a Nonlinear Hydraulic Damping Device

Gale H. Buzzard II, assistant professor, Dept. of Mechanical Engineering, Duke University, Durham, N. C.

Description of an experimental investigation of the dynamic characteristics of an orifice-type, hydraulic damping device and a proposed method for analyzing a system employing such a device.

Although the hydraulic damper has long been used for the dissipation of kinetic energy in mechanical systems, a search of existing literature revealed that very little work had been done in the area of correlating experimental information into useful design data. These data were the objective of this investigation.

ASME Paper No. 61-WA-205, "The Dynamic Response of a Nonlinear Hydraulic Damping Device," presented at the Winter Annual Meeting, New York, November-December, 1961, 8 pp.

TO OBTAIN COPIES of papers or articles abstracted here, write directly to:

ASLE—American Society of Lubrication Engineers, 5 North Wabash Ave., Chicago 2, Ill.; papers 50 cents to members, 75 cents to nonmembers.

ASME—American Society of Mechanical Engineers, United Engineering Center, 345 East 47th St., New York 17, N. Y., papers 50 cents to members, one dollar to nonmembers.

National Telemetering Conference, Proceedings, available from Institute of Aerospace Sciences, 2 East 64th St., New York 21 N. Y.

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Helpful Literature for Design Engineers

For copies of any literature listed, circle Item Number on Yellow Card—page 19

Linear, Rotary Solenoids

Provides detailed specifications on more than 70 different types of linear solenoids, rotary solenoids, and electromagnetic devices. Incorporates both standard and special dc and ac units, and lists electrical and mechanical characteristics for solenoids from 3/4 to 2 1/2 in. diam. Among the electromagnetic devices outlined and illustrated are a three-position message indicator and a number of solenoid-switch combinations. Condensed Catalog WD 301, 6 pages. Western Div., IMC Magnetics Corp., 6058 Walker Ave., Maywood, Calif.

Circle 501 on Page 19

Electric Tape

Shows Slipknot and Plymouth line of electrical tapes, complete with laboratory specifications. Among the new products shown are Slipknot CW vinyl electrical tape, Slipknot filler tape, and Plymprene neoprene splicing compound for oil-resistant applications. 8 pages. Tape Div., Plymouth Rubber Co. Inc., Canton, Mass.

Circle 502 on Page 19

Braided, Twisted Packings

Offers detailed information on 70 standard styles of braided and twisted packings. Contains information on braided packings for service on reciprocating rods, rams, and plungers; centrifugal and rotary shafts; valve stems and expansion joints. Data on each style, designed specifically for certain operating conditions, are given in detail, including materials used and types of construction. Also describes molded asbestos valve rings and lubricating materials. Bulletin AD-191, 20 pages. Garlock Inc., Palmyra, N. Y.

Circle 503 on Page 19

Silicon PNPN Devices

Presents details on the field of low-power silicon PNPN devices. Covers sensitivity and function range of controlled rectifiers, controlled switches, base turn-off devices (Trigistors), light-operated PNPN photocells, and in-line PNPN configurations. Catalog C400, 8 pages. Solid State Products Inc., One Pingree St., Salem, Mass.

Circle 504 on Page 19

Fastener, Rivet Products

Describes line of fastener and rivet products, including head styles and grip ranges, and suggested applications for each type and style. Design and production advantages, strength properties, and suggested hole preparation are treated. Also includes descriptions and illustrations of new Hi-Tensile Huckbolt fastener, Daisy blind rivet, and several special-purpose products. Form 132, 28 pages. Huck Mfg. Co., 7790, Detroit 7, Mich.

Circle 505 on Page 19

Plastic Shapes

Lists available sizes, weights, color ranges, textures, purchasing specifications, grades, and prices for plastic sheets, rods, tubes, films, blocks, and flat tubings. Cements, pigments, and miscellaneous supplies also are listed. Includes expanded comparison table of chemical, electrical, and mechanical properties for 14 plastics families. 64 pages. Cadillac Plastic & Chemical Co., 15111 Second Ave., Detroit 3, Mich.

Circle 506 on Page 19

Speed Reducer

Includes data on ten new herringbone speed reducer sizes added to the catalog line. Includes application data, design details, selection procedures and examples, load characteristics and service factors, backstop selection, overhung load capacities, thermal ratings, horsepower ratings, and dimensions. Bulletin J-26, 44 pages. Dept. PS, Hewitt-Robins, Stamford, Conn.

Circle 507 on Page 19

Contact Relays

Describes JM series mercury-wetted contact relays. Design details of the contact arrangement, and electrical and physical performance characteristics are included. Also contains formulas with which to calculate contact-operating characteristics. Tables of resistance ratings and values of maximum voltages provide a means of selecting the proper relays for specific circuits. Termination wiring diagrams for each series simplifies the right choice of wiring configuration. Form BC167, 8 pages. Potter & Brumfield Div., American Machine & Foundry Co., Princeton, Ind.

Circle 508 on Page 19

Testing and Test Equipment

Addition to "Technical Information For The Engineer" series describes various types of tests applied to synchros, resolvers, servo motors, servomotor generators, gyros, and accelerometers to discover or verify the operational parameters and characteristics of such components. Delineates the theory, procedures, and equipment involved in the proper performance of testing functions. 46 pages. Kearfott Div., General Precision Inc., 1150 McBride Ave., Little Falls, N. J.

Circle 509 on Page 19

Fluid-Power Products

Contains material on W07 variable-displacement hydraulic pump; selector control valves; steel tube and pipe fittings; hose couplings and assemblies; brass tube and pipe fittings; tools and accessories. Data include design, application, performance, size range, and shapes. Catalog C-301, 12 pages. Weatherhead Co., 300 E. 131st St., Cleveland 8, Ohio.

Circle 510 on Page 19

Standard Levers, Rocker Arms

Provides design data, ordering information, and manufacturing applications on a line of standard machine levers and rocker arms. Units are readily adapted to individual machine requirements. 8 pages. Stelron Cam Co., 75-77 Hemlock Drive, Paramus, N. J.

Circle 511 on Page 19

Selenium Photovoltaic Cells

Discusses features and specifications of Models 856 and 594 photovoltaic cells which use barrier-layer, self-generating Photronic components. Application data, dimensions, and component details are provided. Specifications include data on spectral sensitivity and output of both models. Bulletin 03-200B, 4 pages. Weston Instruments Div., Daystrom Inc., 614 Frelinghuysen Ave., Newark 14, N. Y.

Circle 512 on Page 19

Glass-Reinforced Plastics

Describes design advantages of new molded polyester-glass. Also discusses polyester-glass applications and contains a list of mechanical, electrical, and physical properties. 4 pages. National Vulcanized Fibre Co., 1061 Beech St., Wilmington 99, Del.

Circle 513 on Page 19

Filter Assemblies

Covers tee-type filter assemblies for airborne and ground-support use, as well as for industrial applications where high reliability is needed. Consists of a general introduction plus 32 data sheets giving specifications for tube sizes from 1/4 to 2 in., working pressures to 5000 psi, and temperatures from −65 to +1000 F. Bulletin A4, 34 pages. Aircraft Porous Media Inc., Subsidiary, Pall Corp., 30 Sea Cliff Ave., Glen Cove, N. Y.

Circle 514 on Page 19

Here is a major breakthrough in sealing air cylinders...

the new IPC ArchSeal*

REQUIRES NO MECHANICAL ASSIST. It floats . . . it's revolutionary . . . it's so simple in design and so reliable in service you'll wonder how you ever got along without it! IPC's custom engineered ArchSeal is just what the name implies . . . an arched design with *flexing* sides.

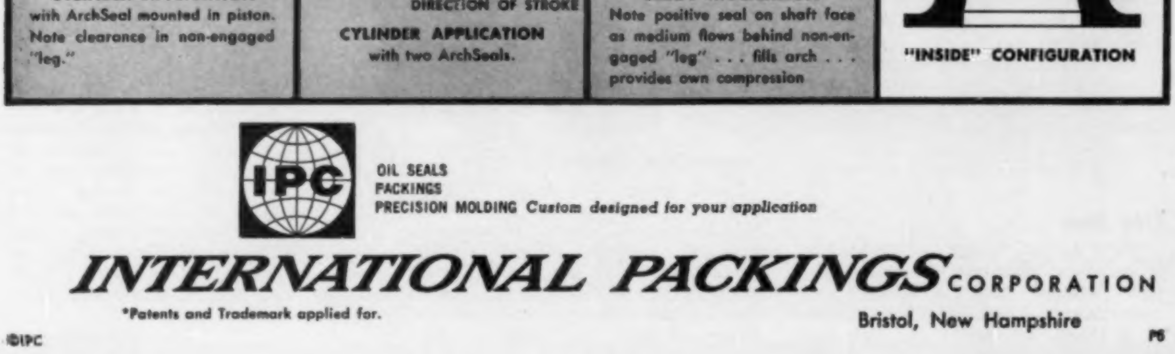
The far "leg" of this new seal moves *away* from the pressure source *instantly* . . . to provide positive sidewall sealing as the air medium flows around the non-contact leg and back-fills the hollow arch. Immediately . . . you get self compression on the *face* of the seal as the air pressure expands the face outward against either shaft or cylinder wall.

That's right! They're made for inside or outside sealing. Reverse the pressure or stroke . . . the seal reacts in the opposite direction with the same positive results!

Reliability? Many are performing perfectly now with over 20,000,000 cycles. Temperature range? From minus 30° up to 500° F.

Here's the *ideal* seal for air cylinders where no lubrication is possible. Here's the way to eliminate expensive assembly components of O-rings, U's or V's with their expanders, back-up rings, or washers. You don't need them! The ArchSeal solves the problem without extra frills.

Oh yes . . . it's an IPC "custom" product so we'll need details on your application. Don't hold back . . . the ArchSeal can be the answer for which you have been looking.



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OIL SEALS
PACKINGS
PRECISION MOLDING *Custom designed for your application*

INTERNATIONAL PACKINGS CORPORATION

*Patents and Trademark applied for.

Bristol, New Hampshire

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P6

Circle 285 on Page 19

Hydraulic Cylinders

Illustrates and describes the operation and application of hydraulic cylinders. Contains a description of Keeper Ring hydraulic cylinders, and includes engineering drawings and specifications of the seven mounting styles. Catalog 106, 12 pages. Rivett Lathe & Grinder Inc., Brighton 35, Boston, Mass.

Circle 515 on Page 19

Miniature Solder Connectors

Contains data on Bantam miniature solder connectors that conform to MIL-C-0026482A (WEP). Catalog includes specifications, dimensional drawings, tables, shell styles, and termination devices for nine shell sizes from No. 8 through No. 24. Additional material explains polarization and specific design details. Catalog BSB, 24 pages. Burndy Corp., Norwalk, Conn.

Circle 516 on Page 19

Mechanical Tubing

Describes basic characteristics and recommended procedures for Type 52100 alloy steel tubing. Contains data on how the tubing is made, tells how to select tubing, and includes tables of temperature and hardness conversion. 42 pages. Peterson Steels Inc., Union, N. J.

Circle 517 on Page 19

Couplings, Clutches

Two new circulars cover variations in design and application of disconnecting safety shaft couplings and free-wheeling clutches. Lists features, gives specifications, and includes data on applications. Circulars 16-C, 17-B, 4 pages. Odin Corp., Castleton, Ind.

Circle 518 on Page 19

AC and DC Voltmeters

Catalogs line of single and multirange ac and dc vacuum-tube and transistorized voltmeters, including militarized models. Includes sections on range selection and scale-plate design, template and outline drawings, and section on phase-sensitive measurement theory. 28 pages. Trio Laboratories Inc., Dupont St., Plainview, L. I., N. Y.

Circle 519 on Page 19

Hydraulic System

Discusses operation of Dynamaster hydraulic remote-control system, through use of line drawings. System eliminates use of large-size tubing for transmitting control fluid. Bulletin RC-100, 4 pages. Dynex Inc., 777 Dynex Drive, Pewaukee, Wis.

Circle 520 on Page 19

Stop Nuts

Offers detailed analysis of advantages of extra-thin, insert-type, self-locking hex nuts. Selection table provides visual cross-reference of available parts compared as to thread size, height, hex flats and cross-corner dimensions; minimum tensile strength; recommended tightening torques. Also includes 26 standard drawings of individual parts. Manual 61111, 28 pages. Elastic Stop Nut Corp. of America, 2330 Vauxhall Rd., Union, N. J.

Circle 521 on Page 19

Thermocouple Selection

Sample board permits quick, easy selection of thermocouples. Units shown satisfy over 90 per cent of standard thermocouple applications. All thermocouples are shown in actual size. They are calibrated to be twice as accurate as standard ISA specifications. Selector is printed on heavy 11 x 14-in. card stock, and is designed for wall mounting. Selector TSB-1. Smith Thermotronics Inc., Conshohocken, Pa.

Circle 522 on Page 19

Flexible Pressure Hose

Nylaflow flexible pressure hose has high resistance to flex, pressure pulse, and vibration fatigue. Bulletin itemizes physical, chemical, thermal, electrical, and installation features of the reinforced nylon hose. Also lists typical applications. Bulletin BR-3Hb, 8 pages. Polymer Corp., 2120 Fairmont Ave., Reading, Pa.

Circle 523 on Page 19

Fractional-Horsepower Motors

Provides data on Classic fhp motors and gear motors in ac-dc universal and dc shunt models. Includes all specifications and dimensions. Points out design details of the units. Form 561A, 4 pages. Carter Motor Co., 2711 W. George St., Chicago 18, Ill.

Circle 524 on Page 19

Perforated Metal

Shows stocked sizes and patterns of perforated metal for ventilation, protection, concealment, construction, and ornamental decoration. Presents round and slotted designs in actual size and lists the name for each pattern. Percentage of open area, gage dimensions, and sheet sizes are shown. Bulletin CD-501, 12 pages. Dept. RDT, National-Standard Co., Niles, Mich.

Circle 525 on Page 19

Miniature Connectors

Describes Series 610, 710, and 810 miniature, nonenvironmental connectors available in 22, 18, and 16 shell size. Includes all specifications and data on available accessories. Bulletin 4007, 10 pages. Consolidated Electrodynamics Corp., 360 Sierra Madre Villa, Pasadena, Calif.

Circle 526 on Page 19

Copper-Clad Laminates

Lists all grades of copper-clad laminated plastics corresponding to NEMA and MIL specifications. Characteristics of each grade are described and typical property values are listed. Also discusses bonding of metal foils to laminates. Tables on thickness tolerance for copper foil and copper-clad sheet, and maximum warp or twist of composite sheet are included, along with availability of sheet sizes, copper foils, and rolled copper foil. 6 pages. Synthane Corp., Oaks, Pa.

Circle 527 on Page 19

Tape Recorders, Perforators

Covers line of perforated-tape readers, perforators, accessories, tape systems. Gives all specifications, includes diagrams of the systems. 8 pages. Tally Register Corp., 1310 Mercer St., Seattle, Wash.

Circle 528 on Page 19

Snap-Action Switch

Describes Cricket switch, a miniature, snap-action unit which uses only two moving parts. Contains dimension drawings, definitions and illustrations of technical terms, and tabular application data. Bulletin 020-101, 4 pages. Electrical Contacts & Specialties Div., Fansteel Metallurgical Corp., North Chicago, Ill.

Circle 529 on Page 19

Industrial Thermocouples

Carries descriptive information on thermocouples for industrial applications. Catalog includes engineering information concerning thermocouple usage and application. Bulletin TC 13A, 56 pages. Barber-Colman Co., Rockford, Ill.

Circle 530 on Page 19

Industrial Plastics

Describes proper selection of industrial plastics. Gives general description of vulcanized fiber, Phenolite laminated plastic, and extruded thermoplastics with typical applications, properties, and forms of each. Also discusses rods and tubes of vulcanized fiber, Phenolite, and nylon. "Selecting The One Best Material," 16 pages. National Vulcanized Fibre Co., 1061 Beech St., Wilmington, Del.

Circle 531 on Page 19

Hermetically Sealed Relays

Lists line of miniature, subminiature, microminiature, and Unimite hermetically sealed relays. Information given on all units includes relay type, coil resistance, voltage or current calibration, basic application curves, vibration specifications, suggested source voltage, available mounting and header configurations. Catalog GEA-6628B, 20 pages. General Electric Co., Schenectady 5, N. Y.

Circle 532 on Page 19

Precision Glass

Lists specific details of inside and outside-diameter tolerances, charts roundness and concentricity for various diameters of tubing. Tolerances for different types of end condition are also covered. Lists complete range of glass from standard borosilicate through metal-sealing glasses, including quartz and Vycor, which are available for redraw. 4 pages. T. H. Garner Co., 177 S. Indian Hill Blvd., Claremont, Calif.

Circle 533 on Page 19

Circle 286 on Page 19→

WHITEY™

MICRO-REGULATING CORROSION RESISTANT LABORATORY FEED PUMP

That a Whitey Pump sells itself is evidenced by the fact that customers who have purchased one invariably purchase another. The reason for this is simple. Unusual design features and extreme quality control assure trouble-free performance and qualify this pump for the most critical research and industrial service.

METAL DIAPHRAGM DESIGN

Hydraulically actuated diaphragm design provides zero leakage pumping. Fluids can never be contaminated by packings or seals and are completely contained by a metal to metal diaphragm seal.

THE PUMP THAT SELLS ITSELF

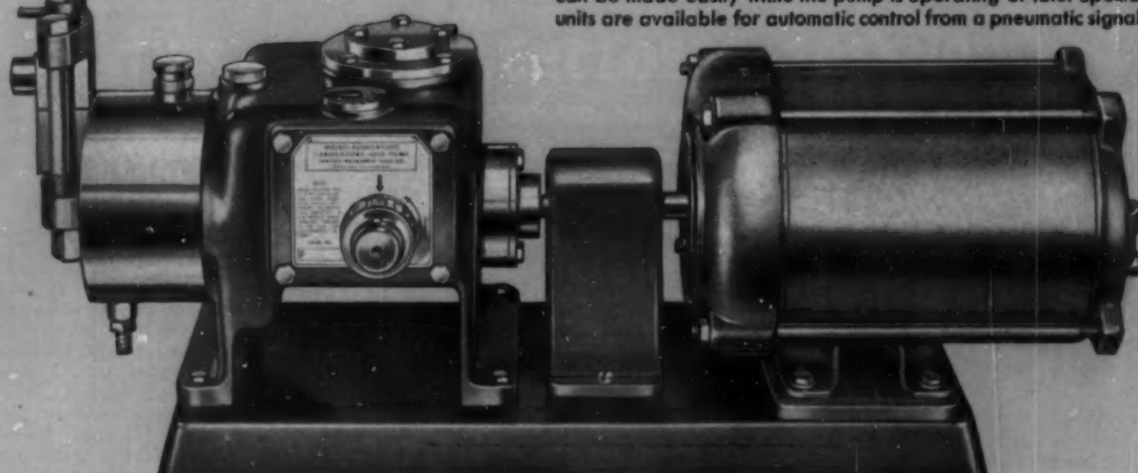
ACCURATE LOW FLOW RATES

The Whitey pump is available for maximum pumping capacity of 2½ gallons per hour. Six different plunger sizes, three standard gear ratios, and three motor speeds offer a flexibility in design to suit your exact requirements. Stroke adjustment permits low flow rates to less than 5 ml per hour.

CORROSION RESISTANT

Type 316 stainless steel is used for all wetted parts for maximum corrosion resistance. Monel, Inconel and Hastelloy are available for special applications. Explosion proof motors are standard equipment on all Whitey Micro-regulating Feed Pumps.

MICROMETER ADJUSTMENT: Micrometer adjustment of stroke length utilizes 10 full turns of the adjustment knob from zero to maximum flow for precise control of pumping rate. Adjustments can be made easily while the pump is operating or idle. Special units are available for automatic control from a pneumatic signal.

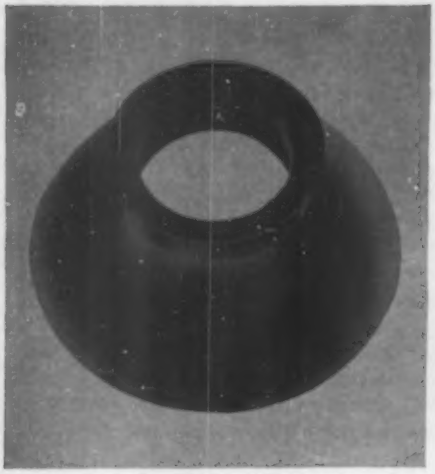


WHITEY FOR EXACTING SERVICE

RESEARCH TOOL CO. • 5525 MARSHALL STREET • OAKLAND 8, CALIFORNIA

ElastaCAST®

SOLVES CRITICAL MATERIAL SELECTION PROBLEMS



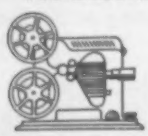
Automotive Ball Joint Seal. *"30,000 miles without ball joint lubrication" resulted from Ford Motor Company's use of oil-resistant ElastaCAST for ball joint seals in its 1961 Fords, Mercurys and Lincoln-Continentals. This application takes advantage of ElastaCAST's abrasion resistance, tear strength, excellent weathering properties and low permanent set.*

If you are planning a product that requires a material with unusual properties, take a look at ElastaCAST. Let us work closely with you, particularly in your early design work; experience has shown us that definite savings in design, production and the finished part generally result.

ElastaCAST is a new liquid polyurethane elastomer possessing an unusual range of mechanical and physical properties — such as outstanding abrasion, tear and ozone resistance, oil and gas resistance and high load-bearing. Here's a whole new sales advantage made possible through our rubber and plastics technology. Call us about your tough or unusual applications.

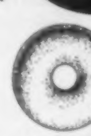
ACUSHNET PROCESS COMPANY
760 Belleville Avenue, New Bedford, Mass.

Acushnet

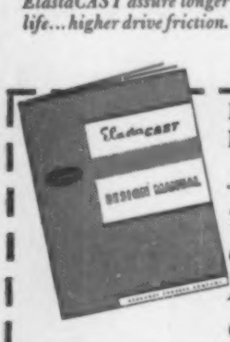


Light Drive Rolls *of ElastaCAST assure longer life... higher drive friction.*

Shoe Toplifts *of ElastaCAST outwear nylon, rubber or leather . . . take impact bearing loads up to 7,000 psi.*



Textile equipment bearings *of ElastaCAST outlast metal as well as conventional rubbers and plastics.*



Please send my copy of your new 16-page ElastaCAST Design Manual.

*Name*____________________

*Title*____________________

*Company*____________________

*Address*____________________

*City*________ *Zone*______ *State*________

Universal Marking System

Describes Mark-Trol universal marking system for round-chart recorders with a completely sealed capillary system and replaceable ink cartridge. System has an operating temperature range of 0 to 145 F. Shows how system can be installed in minutes. 6 pages. Esterbrook Pen Co., 200 Cooper St., Camden 1, N. J.

Circle 534 on Page 19

Tantalum Capacitors

Cross-reference lists, in alpha-numerical order, wet-electrolytic slug and foil tantalum capacitors of other manufacturers along with company's equivalents. Also lists MIL-C-3965B type designations for tantalum slug and foil capacitors with Ohmite commercial equivalents. Summary of MIL-C-3965B specification is also provided. Bulletin 1009, 4 pages. Ohmite Mfg. Co., 3695 Howard St., Skokie, Ill.

Circle 535 on Page 19

Pneumatic Timing Relay

Describes new 1-min pneumatic timing relay, including diagrams, operational features, and a contact rating chart. Relay times periods from 0.2 sec to 1 min on such applications as machine-tool controls and sequence controls for industrial processes. Folder LJ-97, 4 pages. Cutler-Hammer Inc., 328 N. 12th St., Milwaukee 1, Wis.

Circle 536 on Page 19

Valve Operators

Covers construction, basic circuits, applications, torque-capacity tables, dimensions, controls, and accessories of cylinder-type valve operators for plug, ball, and other rotary valves. Lists 59 sizes which cover a range of 200 to 4,000,000 lb-in. of torque. 24 pages. Ledeen Inc., 3350 N. Gilman Rd., El Monte, Calif.

Circle 537 on Page 19

Rotating Components

Describes a line of servomotors, motor tachometers, inertially damped servomotors, and velocity-damped servomotors from sizes 8 through 18. Provides complete tabulations of electrical and mechanical characteristics and outline drawings for the various sizes. Bulletin 1000, 8 pages. Magnetics Div., March Dynamics Inc., 920 S. Oyster Bay Rd., Hicksville, L. I., N. Y.

Circle 538 on Page 19

Magnetic Starter

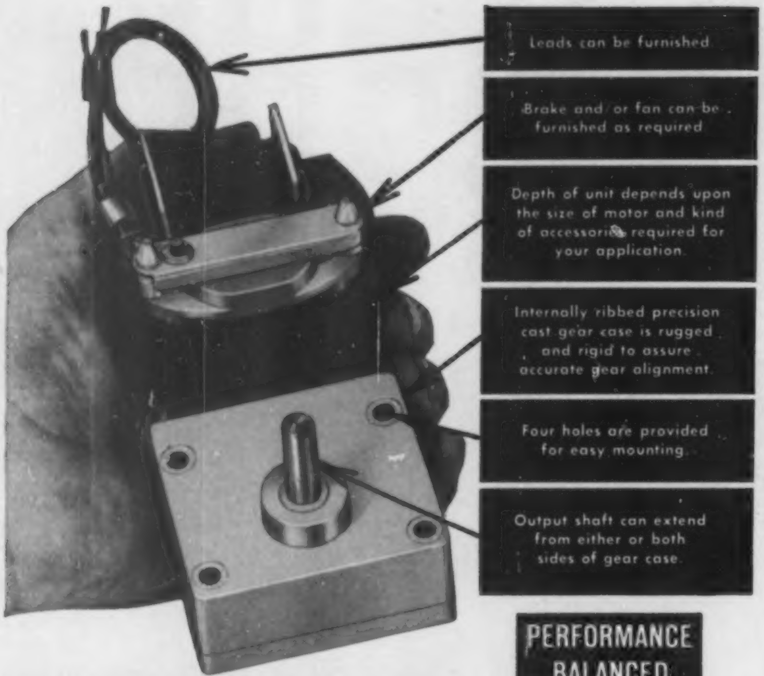
Describes compact Size 3 magnetic starter, including horsepower ratings, dimensions, and electromagnet data. Also contains information on field modification kits and conversion to unit with pushbutton or selector switch, third overload relay, pilot light, or auxiliary contacts. Bulletin 14-B3, 4 pages. Furnas Electric Co., 1045 McKee St., Batavia, Ill.

Circle 539 on Page 19

Circle 287 on Page 19

Circle 288 on Page 19→


19,999,998
19,999,999
20,000,000
CYCLES
THIS VICKERS ENCLOSED SOLENOID
HAS JUST COMPLETED ITS TWENTY-MILLIONTH CYCLE IN ACTUAL, RUGGED SERVICE. IF THE DRY-TYPE SOLENOIDS YOU'RE INCORPORATING INTO YOUR EQUIPMENT ARE CAPABLE OF DOING AS WELL, CONSIDER YOURSELF FORTUNATE. IF THEY AREN'T, IT MIGHT BE A GOOD IDEA TO FIND OUT MORE ABOUT VICKERS SOLENOIDS. REALISTICALLY PRICED, AND FREE FROM THE LEAKAGE PROBLEMS OF OIL-IMMERSED UNITS, THEY'RE IN A CLASS BY THEMSELVES. WRITE FOR BULLETIN 2106-1.
VICKERS INCORPORATED
DIVISION OF SPERRY RAND CORPORATION
ELECTRIC PRODUCTS DIVISION
1881 LOCUST STREET • SAINT LOUIS 3, MISSOURI



PERFORMANCE BALANCED
SINCE 1911

Performance-Balanced — a Merkle-Korff exclusive feature designed to give you more dependability at the lowest possible cost.

MODEL "WF"

New Merkle-Korff FHP Gear Motor

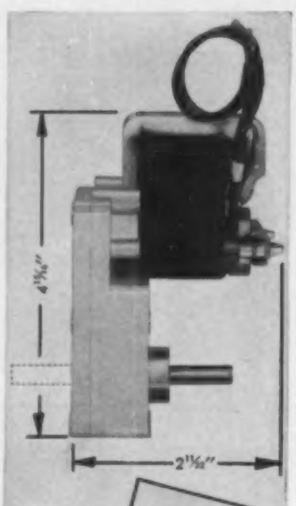
SMALL, FLAT DURABLE, POTENT!

Designed especially for the *Original Equipment Manufacturer* who needs up to 30 lb.-in. of torque in a compact, highly dependable f.h.p. unit—at extremely attractive quantity prices.

The smallest "WF" unit is only 2-21/32" wide, 2-11/32" deep and 4-15/16" high. Depth varies according to motor stack and brake or fan if required.

Precision cut spur gearing is used for long life, quiet operation and is housed in a precision cast, non-ferrous gear case. Two phosphor bronze bearings support the output shaft which can extend from either or both faces of the gear case.

High starting torque, 100% to 120% of full load torque qualifies this Merkle-Korff unit for use where larger, more costly units have previously been required: Vending Machines, Chemical Feed Pumps, Office Equipment, Industrial Control Apparatus, Photographic Equipment and Rotisseries are typical application.



For complete details, write for Bulletin 2000.

MERKLE-KORFF
MK
GEARED MOTORS

MERKLE-KORFF GEAR CO.

215 NORTH MORGAN STREET • CHICAGO 7, ILLINOIS • MOnroe 6-1900

HELPFUL LITERATURE

Vacuum Pumps

Gives specifications for single-stage steam-jet vacuum pumps. Discusses pumps from single to six-stage types and tells when to use each type. Bulletin 5E, 8 pages. Schutte & Koerting Co., JA-40, Cornwells Heights, Bucks County, Pa.

Circle 540 on Page 19

Teflon Fiber Felts

Describes Teflon fiber felts, available in widths to 72 in., lengths to 60 yd, and thicknesses to 1 in. Includes data on properties, availability, and application range. Bulletin 9-61, 3 pages. American Felt Co., 2 Glenville Rd., Glenville, Conn.

Circle 541 on Page 19

Wire and Cable

Permits selection of Flexlead lead wire, coaxial cable, and various combinations of conductors, primary insulations, shielding, and jacketing which are available. Includes RETMA color-coding guide. 4 pages. L. Frank Markel & Sons, Norristown, Pa.

Circle 542 on Page 19

Hydraulic Cylinders

Gives design and performance data on new series DLP cylinders, operating at pressures to 2000 psi. Specifications on bores from 1⅛ through 8 in. are listed. Bulletin HC-1, 20 pages. Denison Engineering Div., American Brake Shoe Co., 1160 Dublin Rd., Columbus, Ohio.

Circle 543 on Page 19

Bendable Tubing

Describes Plica hand-bendable tubing in sizes from ⅜ to 2 in. ID. Gives construction, specifications, and applications. Bulletin 61-A, 4 pages. Flexaust Co., Div., Callahan Mining Corp., 100 Park Ave., New York 17, N. Y.

Circle 544 on Page 19

Rotary Solenoids

Contains technical data on eight basic sizes in rotary solenoid designs. Tells how to use solenoid data in actuating applications, and lists details on 222 models carried in stock. Sizes range from 1 in. diam by ⅝ in. high to 3⅜ in. diam by 2-5/16 in. high. Standard strokes are available from 25 to 95 deg, right and left hand. Torque outputs range from 0.15 to 98 lb-in. Catalog C-961, 32 pages. Ledex Inc., 123 Webster St., Dayton 2, Ohio.

Circle 545 on Page 19

Filter Assemblies

Provides data on wire-cloth filter and strainer assemblies. Illustrates many units, and discusses Micro-Chek micronic filtration. Shows various types of woven-wire cloth, and includes actual samples. Gives all specifications for the material. Bulletin MC-3, 24 pages. Write on company letterhead to Wire Cloth Products Inc., 2801 Congress Expressway, Bellwood, Ill.

Circle 289 on Page 19

5 REASONS FOR SPECIFYING U.E. INDICATING TEMPERATURE CONTROLS

* **HIGH SENSITIVITY**... on-off differentials from ± .5° F with excellent repeatability
* **LOW COST** . . . list prices from $35.00 with generous quantity discounts
* **EASY MAINTENANCE** . . . thermal assemblies quickly replaced in the field with no loss of calibration accuracy
* **PROVEN DEPENDABILITY**... reliable liquid-filled measuring systems combined with simple service-proven components for accurate performance and long life
* **GREATER VERSATILITY**... many styles, ranges, sensing elements and switch characteristics permit hundreds of "custom-built" combinations

ALL PURPOSE

-150° to +650° F

A sensitive wide range unit with control point accuracy equivalent to individually calibrated instruments. 10" rotating scale permits unusual readability and close settings. Available with dual switches for controlling two independent circuits.

E 32N

E 36N

LOW COST... (800 Series) -150° to +650° F
Short dial spans of 50 to 200° F permit compact design only slightly higher in price than non-indicating controls. Available with dual switches.

HIGH TEMPERATURE . . . (900 Series) 0° to +1000°F
A NEW high temperature series with rugged stainless steel mercury filled thermal systems.

For the USUAL or UNUSUAL application, United Electric offers quality controls at economical prices.

E 65N

SPACE SAVING... -150° to +650° F
Skeleton design permits direct incorporation into equipment—saving cost of enclosure. Many models with dial spans of 50 to 200°F. Available with face plate for panel mounting.

E45N

SPECIAL PURPOSE.... -150° to +1000°F
Shown here is a typical Special Purpose control used on medical equipment, such as baby incubators, etc. WHAT IS YOUR REQUIREMENT? Chances are one of our standard controls will satisfy your needs. If not, we'll put our 30 years' experience to work for you on special designs.

UNITED ELECTRIC CONTROLS CO.
95 School Street
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Write TODAY for complete specifications and price information on U. E. Indicating Temperature Controls, Attention Dept. W.

NAME__________ TITLE__________

COMPANY__________

ADDRESS__________

CITY__________ STATE__________

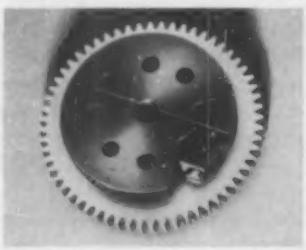
New Parts and Materials

Use Yellow Card, page 19, to obtain more information

Miniature Slip Clutch

maintains constant slip torque

New slip clutch, 5/16 in. thick and 1 in. in diam, delivers up to 3 lb-in. of torque. Nonadjustable unit retains constant slip torque over long cyclic life. Clutch incorporates an output hub with integral gear, piloted on the input hub. Pin on the face of the input hub fits between the ends of a single-turn



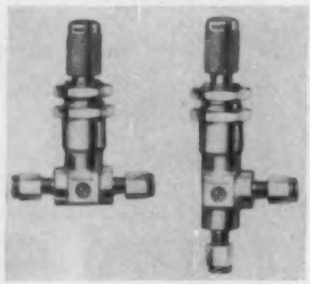
spring fitted to the output hub. Torque is normally transmitted from input hub and pin to output hub via the spring. When output torque exceeds slip rating, single-turn spring slips on the output hub. By adding additional single-turn springs, each increasing the over-all assembly length by 1/16 in., maximum slip torque of 35 lb-in. can be developed. **Precision Specialties Inc.**, P. O. Box 118, Pitman, N. J.

Circle 546 on Page 19

Fine Metering Valve

for 1/16-in. OD tubing

Nupro Very Fine metering valve provides flow control in low flow ranges with minimum dead space. Small valve capacity provides a choking effect to fluid flow, eliminating flow surge on initial adjustment. Valve has Swagelok tube-fitting connections for 1/16-in. OD tubing. Flow control is in the 0 to 50 cc per min air-flow range. O-ring seal



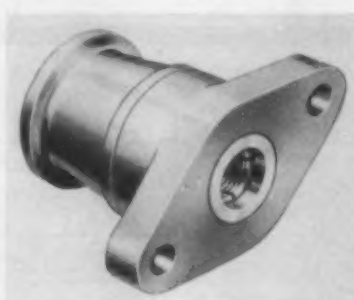
provides sealing below stem threads to protect threads from possible system contamination. Set-screw locking on knurled handle permits locking the adjustment at any desired position. Valve is available in straight or angle-pattern styles in cadmium-plated brass or Type 316 stainless steel. **Nuclear Products Co.**, 15635 Saranac Rd., Cleveland 10, Ohio.

Circle 547 on Page 19

Captive Nut

for separation systems is shrouded type

SN1300 captive-type separation nut consists of a basic SN1100 separation nut enclosed in a base and shroud. Base can be reused after firing. Unit can be torqued to full value from either the bolt or nut end. Separation system is activated by electrically ignited PC10 power cartridge. Housing or shroud retains all the segments after def-



lagration to prevent shrapnel-like damage to delicate components within the vehicle or payload. Nut has ultimate tensile strength from 160,000 to 180,000 psi. It can be ordered in standard thread sizes and grip lengths. Separation can be achieved within 2 millisec. **Hi-Shear Corp.**, 2600 W. 27th St., Torrance, Calif.

Circle 548 on Page 19

Toggle Switch

for subminiature electronic devices

New toggle switch, measuring $\frac{1}{4}$ x $\frac{1}{4}$ x $\frac{1}{8}$ in., is made almost entirely of silver. For use in subminiature electronic devices, switch is virtually corrosion proof and has long life expectancy. Spring is stain-

less steel, heavily silver-plated, and bearing is gold-plated. Switch is a 50-v, 1-amp unit. **Micro-Miniature Controls Div., Otarion Listener Corp.**, Box 711, Ossining, N. Y.

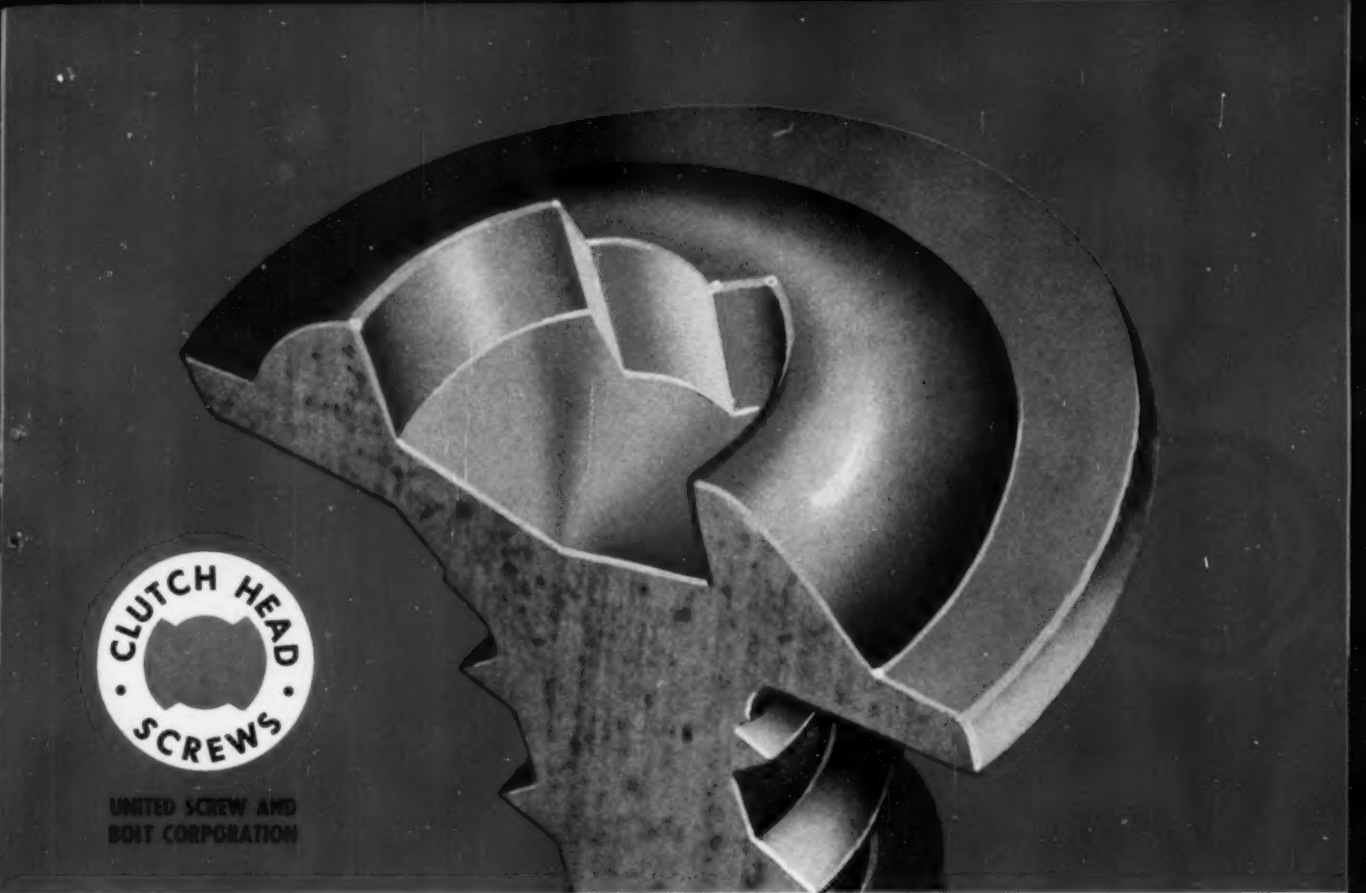
Circle 549 on Page 19

Vinyl-Plastic Coating

withstands heat to 250 F

Liquid Vinyl is a clear, watertight coating that goes on and covers like paint. It gives a tough, flexible finish that will not crack, chip, or peel. Coating resists alcohol, salt, mildew, acid, kerosene, fatty acids, and industrial soil. It applies easily

Circle 291 on Page 19→



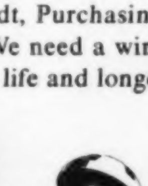
flowability IS THE SECRET!

BIG HEAD—LARGE BEARING WASHER—THIN SHOULDERS—DEEP, WIDE RECESS—STRAIGHT WALLS—SHARP CORNERS—these are tough specifications that prove the flowability of wire. To successfully produce this fastener requires them all. This is why United Screw and Bolt Corp., Chicago, Illinois, specifies Keystone Special Process Wire for this screw.

K. F. Schmidt, Purchasing Agent for United, says, "We need a wire that gives us improved die life and longer runs. Our experience shows the flowability characteristics of Keystone Wire permit us to cold head exactly to specifications. We find the uniformity of Keystone Wire assures successful production of these clutch head fasteners."

It will pay you to investigate the flowability of Keystone Wire. This may give you that extra advantage you need to cold head more difficult jobs—get greater production—reduce machine downtime—increase die life—make more profit. We'll help you find out.

KEYSTONE SPECIAL PROCESS WIRE STUDY



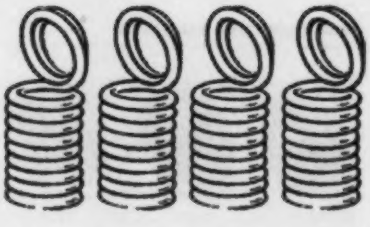
Keystone Steel & Wire Company, Peoria, Illinois

KEYSTONE

WIRE FOR INDUSTRY

MADE AT PEORIA, ILLINOIS, U.S.A.

The Porter Alloyist delivers the right alloy IN THE SPOTS THAT COUNT

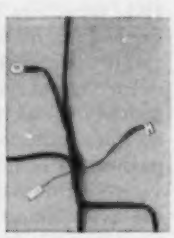


In a split second, the parachute will leap from the pack, released by five special stainless steel springs. Can you think of a tougher spot for reliable performance? Now—and every other time—the springs must work *perfectly*, must keep their shape, unfailing strength and resistance to low temperatures. It's a job for exactly the *right alloy*—recommended and supplied by the Porter Alloyist.

THE PORTER ALLOYIST IS A SPECIALIST IN A WIDE RANGE OF SPECIAL METALS

Porter's Riverside-Alloy Metal Division is your single reliable source for specialty alloys in 8 basic groups of wire, rod and strip . . . phosphor bronze, nickel silver, cupro nickel, brass, stainless steel, nickel, Monel and Inconel.

Ask for a free copy of "Alloys for Industry" describing our wide range of specialty alloys. Write H. K. Porter Company, Inc., Riverside-Alloy Metal Division, Riverside, N. J. Or contact our sales offices in Hartford, Chicago, East Orange, Atlanta, Cleveland, Detroit, Cincinnati, Los Angeles and Rochester.



PORTER cupro nickel wire carries the workload in telephone switchboards.

PORTER supplies bronze and brass strip for wiring harnesses in automotive and marine electrical systems.

PORTER

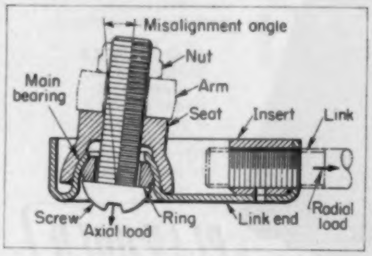
RIVERSIDE-ALLOY METAL DIVISION
H. K. PORTER COMPANY, INC.

by brush, dip, spray, or roller, resists heat to 250 F, and dries in 30 min. It is available in ½ and 1-gal cans. **A. L. Okun Co. Inc.**, 109-02 Van Wyck Expressway, Jamaica 20, N. Y.

Circle 550 on Page 19

Linkage Joints

have positive stop for misalignment angle at 11 deg



Type F ball joints can be used to replace rod ends, SAE ball joints, and other self-aligning joints. Use of low-friction Delrin in area contact with steel provides equal static and dynamic coefficients of friction for oscillating and intermittent motions, and permits use in temperatures from −40 to +250 F. Units are unaffected by any solvent. Positive stop is provided for misalignment angle at 11 deg. **Link-Age Corp.**, 115 Bennett Ave., Yonkers 2, N. Y.

Circle 551 on Page 19

Arched Seal

for shaft or cylinder walls

Designed around a definite arch, with flexing legs or sides, ArchSeal provides its own compression or expansion and requires no mechanical assist. In service, one "leg" of the seal is activated by the pressure source instantly to provide positive sidewall sealing as the air medium flows around the noncontact leg and back fills the hollow arch. This causes expansion of the seal face

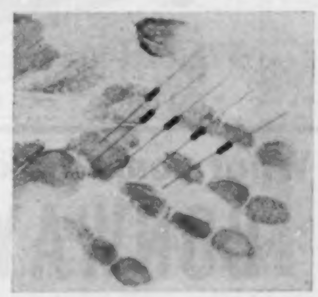
against either shaft or cylinder wall. Reversing the pressure reverses the action and seal reacts immediately. Seal is available in both inside or outside configurations to accommodate temperatures from −30 to +500 F. **International Packings Corp.**, Bristol, N. H.

Circle 552 on Page 19

Silicon Rectifiers

for use in small spaces

Diffused-junction, silicon subminiature rectifiers have an operating capability of 50 ma dc rating at 200 C ambient temperature. Six models are designated JEDEC types 1N3544 through 1N3549. Rectifiers are classed as general-purpose industrial devices to be used where space is at a premium. Low reverse current of the rectifiers makes them suited for magnetic-amplifier applications. Other applications in-



clude missile ground-support equipment, guidance systems, and aircraft-control circuits. Six models differ by continuous peak reverse voltage ratings, which range from 100 v for the 1N3544 to 600 v for the 1N3549. **Rectifier Components Dept., General Electric Co.,** West Genesee St., Auburn, N. Y.

Circle 553 on Page 19

Idler Pulleys

use oil-impregnated sleeve bearings

New Series 0 idler pulleys are available for use as belt tighteners, clutches, direction changers, guides, and idlers. Utilizing oil-impregnated sleeve bearings, units are used where loads and/or speeds are light and cost must be minimized. Idler units are mounted with a standard No. ⅜-16 bolt and washer. When

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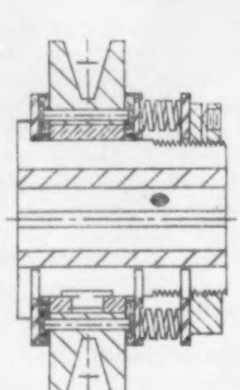
Circle 293 on Page 19

What some folks won't do to use a

CONWAY CLUTCH!



TORQUE LIMITERS, ANYONE?

YUP! IT FIGURES!

Q. Did you know that there is no known way to calculate the force exerted by a Belleville spring?

A. Yup!

Q. Did you know that *there is a way* to calculate the force exerted by a *coil spring?*

A. Yup!

Q. Did you know that if we don't know the force we can never calculate the torque?

A. Yup!

Q. Do you use CONWAY—the coil spring Torque limiter?

A. Yup!

IT FIGURES!

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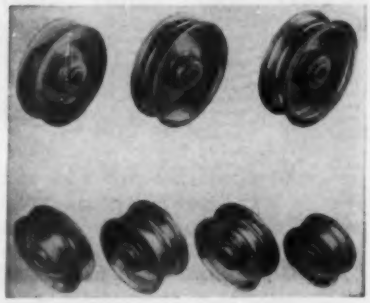


other than this mounting is required, pulleys can be ordered with outer bushing only. To allow clearance for installed pulleys, face of inner bushing extends 1/32-in. beyond face of outer bushing. Both bushings are oil-impregnated sintered metal. Sheave designs are for both V and flat belts, and units are made in diameters from 2 to 3-7/32 in. **New Hampshire Industries Inc.**, Hanover, N. H.

Circle 554 on Page 19

Tantalum-Film Circuits

in a wide variety of digital and linear types

New technique allows advantages of conventional microcomponents to be combined with a single tantalum film from which are fabricated the passive components necessary to the circuit. Microminature transistors and diodes are used for the active elements of the circuits. Resistors and capacitors are formed by a single film of tantalum within accurate tolerances. Each finished circuit is encapsulated for physical protection and portions of the circuit are protected additionally by a passivating oxide coating. Wide variety of digital and linear circuits are available. Circuit values of resistance and capacitance are available for most circuits which operate

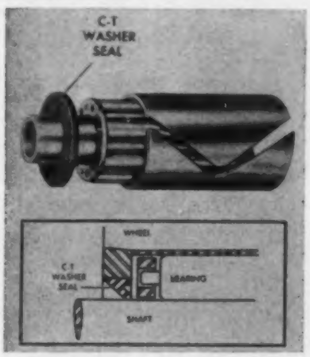
into the video amplifier range of frequencies. Circuit values of capacitance range to 100,000 pf and resistance values to approximately 500,000 ohms are available. **Components Div., Texas Instruments Inc.,** P. O. Box 5012, Dallas 22, Tex.

Circle 555 on Page 19

Washer-Seals

for use with journal-type roller bearings

New Washer-Seals provide a positive sealing action on the shaft, and ensure protection against loss of bearing lubricant from within, while keeping dirt and other foreign particles out. Units replace the retainer washer normally used to position the



bearing. They require no change in machining tolerances, assembly methods, or bearing sizes, and are available for a wide range of popular-size bearings. **Corlett-Turner Co.,** 9145 King St., Franklin Park, Ill.

Circle 556 on Page 19

Slip Clutches

for potentiometer drives

New units control or limit input torque of potentiometers as used in a servo system or other power packages. They are sealed and lubricated for life. Because of their small size, clutches are suited to servo designs and power packages where space is critical. They are effective when used to drive a potentiometer to a positive stop, or to protect against overload from overtravel. Three basic bore sizes accommodate standard potentiometer shafts of 1/8, 3/16, and 1/4-in.

CUT YOUR INDICATOR LIGHT COSTS!

Use G-E Glow Lamps

with resistor attached

You may be paying more than you should for your indicator lights if you're using anything but General Electric glow lamps with the resistor attached. The popular NE-2H and NE-2E, for instance, in large quantities, cost less than seven cents apiece including the resistor.

Low cost isn't the only reason why G-E glow lamps make ideal indicator lamps. They have tremendously long life. Up to 25,000 hours. If you were using one on a coffee pot, that would be about 1,500,000 cups of coffee.

Other big advantages of G-E glow lamps are their rugged construction, small size (shown actual size above) and low power consumption. They run on line voltage with no transformer required and use only a small fraction of a watt. A word to the wise: if you're designing appliances, business machines or military hardware, get the story on General Electric glow lamps as indicators. There are over 60. Write: General Electric Co., Miniature Lamp Dept. M-145, Nela Park, Cleveland 12, Ohio.

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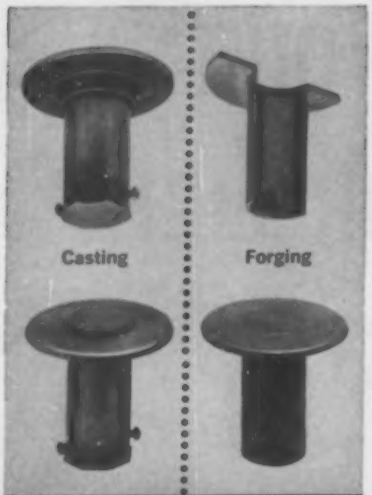
Circle 295 on Page 19



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Originally, a casting requiring heavy cutting, a tube, a web plate and 3 rivets were required. Now a one-piece brass cored forging is polished and plated without machining—and the blanked out web provides the cap.

This stanchion socket benefits from 5 common Cored Forgings advantages.

✓	no draft, I.D. or O.D.
	denser, stronger grain
✓	less machining to finish
✓	less assembly required
	thinner walls or sections
	better appearance
	multiple coring
✓	lower cost plating
✓	less scrap/rejects

Which of these process savings or product improvements would apply to *your* part or assembly? Write for descriptive brochure...or send your parts or drawings for our evaluation...to:

CORED FORGINGS DIVISION
BRIDGEPORT
BRASS COMPANY
1000 Connecticut Ave., South Norwalk, Conn.

Circle 296 on Page 19

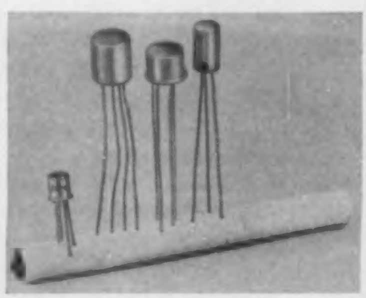
diam. Over-all lengths are $\frac{1}{4}$ to 5/16 in., and outside diameters are 7/16 to $\frac{3}{8}$ in. Torque capacities range from 1 to 20 oz-in. **Sentinel Standard**, 426 E. 102nd St., Brooklyn 36, N. Y.

Circle 557 on Page 19

Subminiature Transistors

in four-lead, TO-18 cases

Four subminiature germanium alloy mesa RF transistors, mounted in four-lead, TO-18 cases, are available for fm and am pocket portable radios. Three constitute a high-frequency fm kit: The 2N990, 2N991, and 2N992 are respectively an RF amplifier, oscillator-mixer, and an IF amplifier. The fourth, the 2N993, is a universal type for use in the standard-broadcast and short-wave bands up to 6 mc in all stages from RF through IF. Transistors have low collector leakage current, high current gain, and high collector-base breakdown voltage. They maintain performance at supply voltages as low as 3 v. **Semiconductor & Special Purpose Tube Div., Amperex Electronic Corp.**, 230 Duffy Ave., Hicksville, L. I., N. Y.

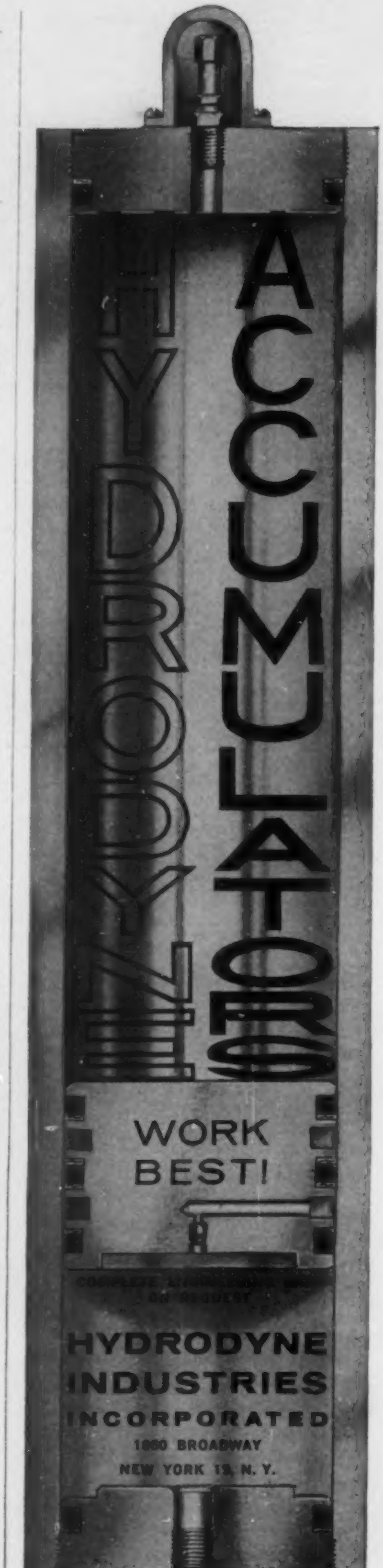


Circle 558 on Page 19

Needle Valve

in stainless steel or brass construction

Model 3000 instrument needle valve can be used in many industrial



Circle 297 on Page 19

applications handling gases or fluids. It is currently available in either Type 316 stainless steel or brass construction. Operating pressure in Type 316 stainless steel is 4500 psi, and 3000 psi in brass. Valve is available in 1/8 and 1/4-in. size with NPTF Dri-Seal pipe threads. For tube porting it is available in AND 10050 or MS33656. Unit is

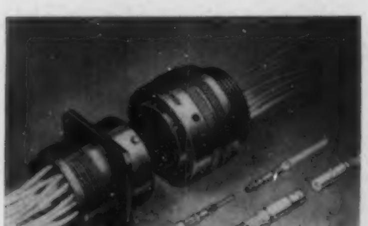
available for regular or panel mounting. Dragon Engineering Co. Inc., 13457 Excelsior Drive, Norwalk, Calif.

Circle 559 on Page 19

Miniature Connector

has crimp-type, removable contacts

Hyfen Bantam miniature, round connector mates with or replaces connectors conforming to MIL-C-26482, under a controlled environment. Connector is available in eight shell sizes and in other configurations in addition to those which conform to MIL-C-26482. Other configurations accommodate combinations of standard and/or miniature coaxial contacts. All contacts are crimp-type, removable, replaceable contacts which snap-lock into the connector, permitting replacement of individual contacts rather than replacing complete connectors. Contacts are high-conductivity copper alloy, gold plated for protection against corrosion and for minimum



(Please turn to Page 184)

solve space problems in power seat

Here's why Chrysler Corporation uses flexible shafts in its six-way motion, power operated seat adjuster:

1. **SPACE ECONOMY** ... "flexible shafts provided means to transmit power from a single electric motor, without compromising seat design."

2. **REDUCED STRESSES** ... "flexible shafts act as torsion bars to reduce motor armature stresses induced when the mechanism was stopped or stalled suddenly."

3. **RELIABILITY** ... "not a single shaft fatigue failure reported from the field to date."

4. **LOW COST** ... "flexible shafts definitely represented savings without sacrificing design advantages."

Investigate for yourself how flexible shafts can solve many of your design problems and at the same time reduce costs!

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IN FLEXIBLE SHAFTS

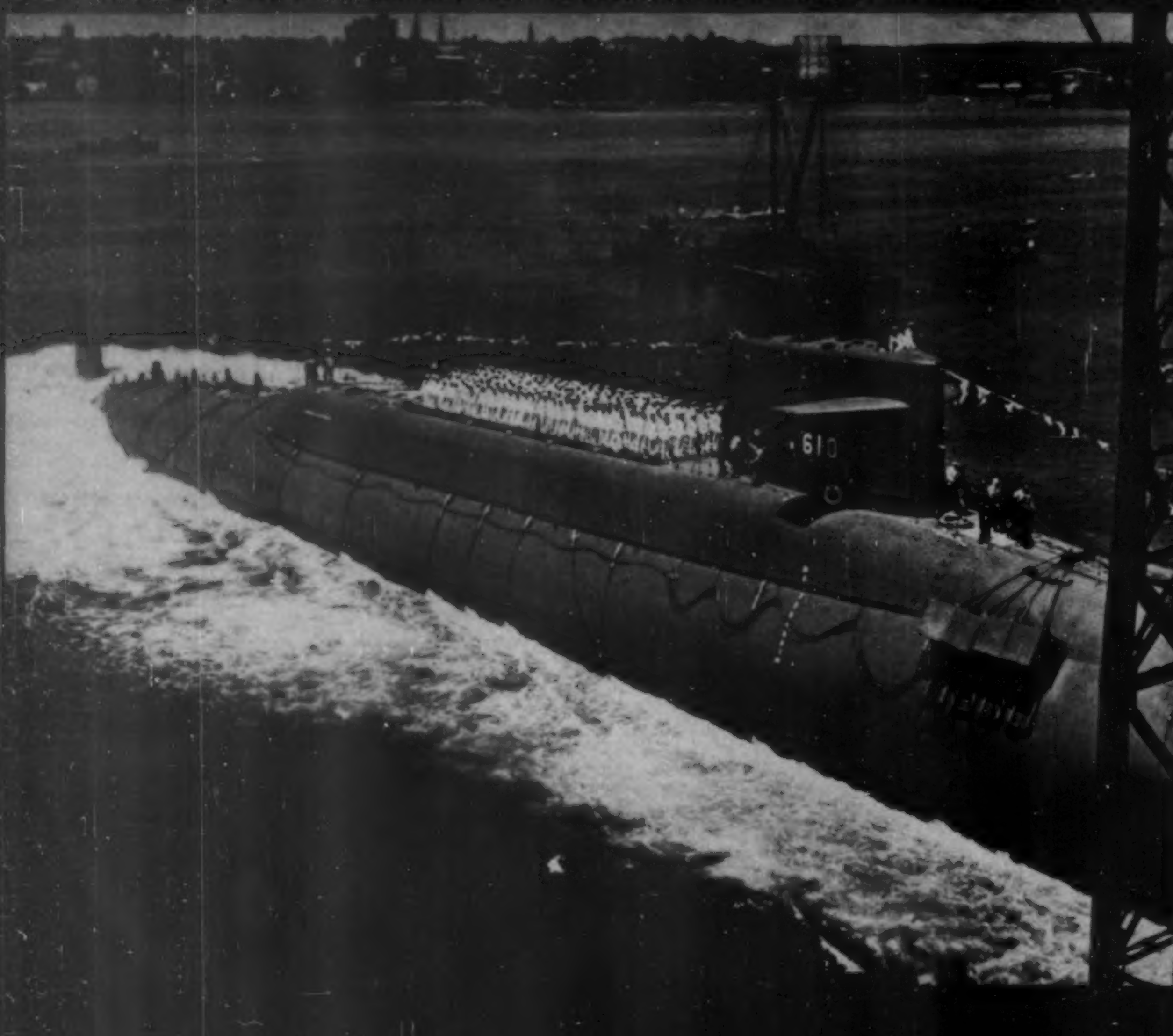
Circle 298 on Page 19

Thomas A. Edison would have been proud of his nuclear namesake

While Thomas Alva Edison is best known for his invention of the electric light, he must also be counted as one of the fathers of modern naval research. In 1915 he became head of the Naval Consulting Board, now known as the Office of Naval Research. He rendered invaluable service to the nation during World War I.

This mark tells you a product is made of tough, dependable Steel.

USS HY-80 armor plate was used for critical hull components in many of these nuclear-powered



The USS Thomas A. Edison is the eleventh nuclear submarine to be launched by General Dynamics Corporation's Electric Boat Division. It is a sister ship of the Ethan Allen launched last year and the fourth submarine designed to fire Polaris missiles that "EB" has built.

In requesting more funds for Polaris submarines, President John F. Kennedy said, "The sooner they are on station, the safer we will be." The chairman of the Joint Congressional Committee on Atomic Energy, Senator Clinton Anderson, has said that the nuclear-powered ballistic-missile submarine marks the closest approach now foreseeable to an ultimate deterrent.

As part of the Navy-Industry team that is producing nuclear submarines, United States Steel has already supplied thousands of tons of HY-80 armor plate (MIL-S-16216). This steel is a U. S. Navy/U. S. Steel development that helped make today's modern submarine design possible. Imagine the properties needed to withstand a *depth charge attack* while under deep-submergence pressure. HY-80 armor plate has the high yield strength and exceptional shock resistance required; yet it can be cold formed and welded readily. This same armor plate assures maximum protection for many areas in our new aircraft carriers and other modern warships.

For landing craft, personnel carriers and tanks, other special grades of armor plate are available to fit specific applications.

If you are designing or building such equipment, United States Steel can supply a special steel to fit your needs. In fact, certain HY-80 rolled structural steel shapes are now available in a fairly large range of sizes and weights per foot.

For more information, or for a properties card on HY-80 plates and shapes, write United States Steel, 525 William Penn Place, Pittsburgh 30, Pennsylvania.

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submarines built by Electric Boat Division, General Dynamics Corporation, Groton, Connecticut.

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TRITON Nuclear-powered radar picket submarine. Two reactors.

SKATE Nuclear-powered attack submarine. Prototype of its class.

SEAWOLF World's second nuclear-powered submarine.

NAUTILUS World's first nuclear-powered submarine.

(Continued from Page 181)

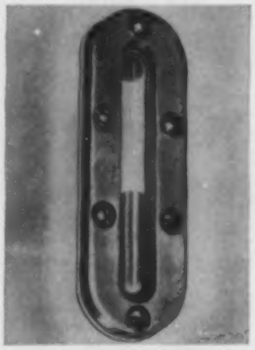
contact resistance. Socket contacts are closed entry design to prevent oversize probe damage. Shells are lightweight, high-strength aluminum alloy, cadmium plated with olive-drab iridite finish per QQ-P-416. **Burndy Corp., Norwalk, Conn.**

Circle 560 on Page 19

Liquid-Level Gages

for level variations from 1¾ to 5 in.

See-Level gages for industrial applications are available for use wherever a visible check is required of the actual level of liquid and/or its rise or fall over a particular range. Gages are available in three sizes providing for level variations from 1¾ through 5 in. Gages are aluminum alloy with a clear-plastic



gage glass backed by a bright reflector. They give a clear view of the level, even from a distance. Mounting surface requires only tapped holes for fastening screws and two ½-in. through holes. **Technical Development Co., 305 S. Chester Pike, Glenolden, Pa.**

Circle 561 on Page 19

Flange-Bearing Assembly

for shaft sizes of 7/16, ½, ⅝ in.

Series 0058 two-bolt flange bearing is available for use in home appliances and light machinery applications. Bearing has permanent lubrication and sintered-bronze bushing. It is available for shaft sizes of 7/16, ½, and ⅝ in. Bearing cartridge, consisting of a ball assembly and a static-conducting rubber liner, is pressed into a 20-gage, cadmium-

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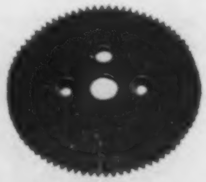
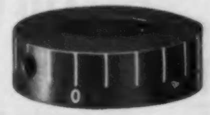
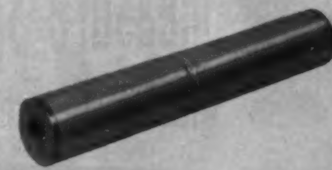


1 Noiseless aircraft gear provides strength, light weight, close tolerances, and eliminates electric shorts or possibility of leaks, reduces costs. Made of INSUROK® T-827.

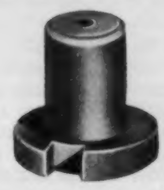


2 This piece replaces steel adjusting collars, speeds up press time, provides clearer markings, will NOT rust, saves $8.35 per piece. INSUROK T-615 was used.

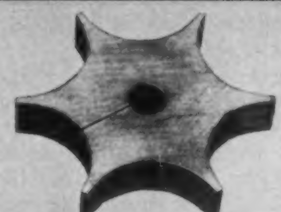


3 Fabricated tube ends duplicating machine problems by resisting developing solutions at less cost than stainless steel or other plastics. INSUROK T-303 and T-643 were used.

TEN CASE HISTORIES SHOW YOU HOW TO LOWER COSTS, SPEED PRODUCTION, IMPROVE PRODUCTS WITH RICHARDSON FABRICATED PARTS

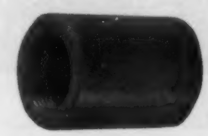


4 Laminated firing pin eliminates cracking during close tolerance machining, cuts production costs $10.00 per thousand, reduces scrap losses. INSUROK T-643 worked perfectly.

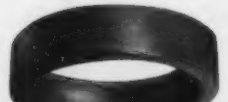


5 Substantially lower priced, easier on products, star wheel replaces and outlasts metal or rubber types, acts as safety device. Made from INSUROK T-601.

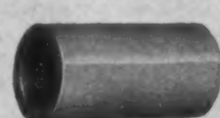
6 Close tolerance fabricated control plate terminal provides clearer markings, is uniform in quality, saves customers $1200 per year. INSUROK T-814 solved the problem.



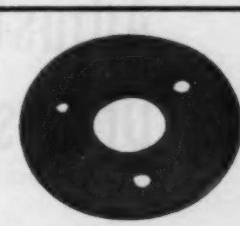
7 Safer laminated tube motor brush holder replaces nylon type because of lower moisture absorption, greater strength and insulation properties. INSUROK TR-303 did the job.



8 This road grader pivot bearing stands up where metals fail, is self-lubricating, provides rugged long life, trouble-free service. Made from graphitized INSUROK T-602.



9 Color-coded sign spacers replace metal, reduce original costs by 10%, eliminate corrosion problems, speed assembly. Solved with INSUROK T-301-TR.



10 Plastic air cylinder cup follower saves 40% in costs, eliminates scratches on cylinder walls, weighs less. INSUROK T-640 replaced metal.

For complete details on any of the above examples, circle the number(s) and return this coupon.

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Circle 300 on Page 19

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Circle 301 on Page 19

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plated steel housing which permits either vertical or horizontal mounting using two 5/16-in. bolts. Randall Graphite Bearings Inc., Box 1258, Lima, Ohio.

Circle 562 on Page 19

Paper-Base Laminate

has good dimensional stability

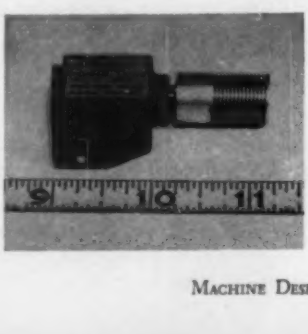
Fireban 330 NEMA-grade XXXPC paper-base, phenolic-resin laminate combines flame retardance with high electrical insulation and cold-punching properties. It also has good dimensional stability. Laminate is available in sheets about 49 x 49 in. and in thicknesses of 0.020 to 0.25 in. It is also furnished with rolled or electrolytically deposited copper foil on one or both sides for making printed circuits. Copper-clad type is furnished in sheets approximately 36 x 48 in., in thicknesses from 1/32 to 1/8 in., with 1 or 2 oz of copper. Copper foil has a minimum purity of 99.5 per cent. Taylor Fibre Co., Norristown, Pa.

Circle 563 on Page 19

Miniature Fluid Valve

senses temperature change of 1 deg

Model 2280 thermally-actuated valve controls the flow of air in life environment systems and similar applications. It weighs only 1¼ oz, and thermal head is 1 in. long by



½ in. diam. Unit senses temperature change of 1 deg, opens or closes to allow fresh air to flow from a liquid-air source. Valve requires no external power or controls. Available for closing settings from 30 to 150 F, unit withstands ambient temperatures of −65 to +160 F. It contains a fixed bypass orifice which allows an exact flow of 7 scfm. In fully opened position, needle valve allows a flow of 10 scfm. Valve is aluminum and stainless steel. **Pyrodyne Inc.**, 11876 Wilshire Blvd., Los Angeles 25, Calif.

Circle 564 on Page 19

Miniature Metal Sections

for industrial use

Miniature roll-formed metal sections are available from stock and on a custom basis for industrial use.

Shapes include angles, channels, and tubes in various sizes. **Universal Molding Co.**, Lynwood, Calif.

Circle 565 on Page 19

Electric Motors

in ratings from 1 to 7½ hp have short axial length

New compact motors have shorter axial length than other motors of similar horsepower ratings. They are available in ratings from 1 to 7½ hp, in speeds through 3600 rpm. Line will soon include ratings to 15 hp. Fractional-horsepower motors are also furnished in a modified compact design. Motors are made over either a flange mounting or a NEMA Type-C machined-face mounting. Types of construction include totally enclosed, fan-cooled (shown); totally enclosed, nonventilated; and propeller-fan duty types. Ribbed housing speeds dissipation of heat. Motors incorporate prelubri-

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IN *your* COMPRESSORS

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Where excess lubrication creates a contamination problem, FLUR-O-FRAN packing and piston rings permit improved operation by reducing drastically the lube oil required. In dry or non-lube service, such as instrument air or food processing, FLUR-O-FRAN performs in an outstanding manner.

LONG LIFE — REDUCED WEAR

In addition to the advantage of better sealing, rod and cylinder wear are much less with FLUR-O-FRAN than with other materials normally used for compressor packing and piston rings. On record are compressors, using FLUR-O-FRAN, that have run for over two years that are still operating with no measurable rod wear.

GREATER DURABILITY

FLUR-O-FRAN is not brittle, it is not subject to chipping or breakage, nor is it vulnerable to damage from scratches. Due to a special process used in its production, FLUR-O-FRAN is dimensionally stable in service as well as in long time storage.

OPERATING ECONOMY

The combined advantages of FLUR-O-FRAN rings will save many dollars for any compressor operator.

EXPERIENCE — SERVICE

France Packing has years of practical experience behind its recommendations and the best production facilities and field service available.

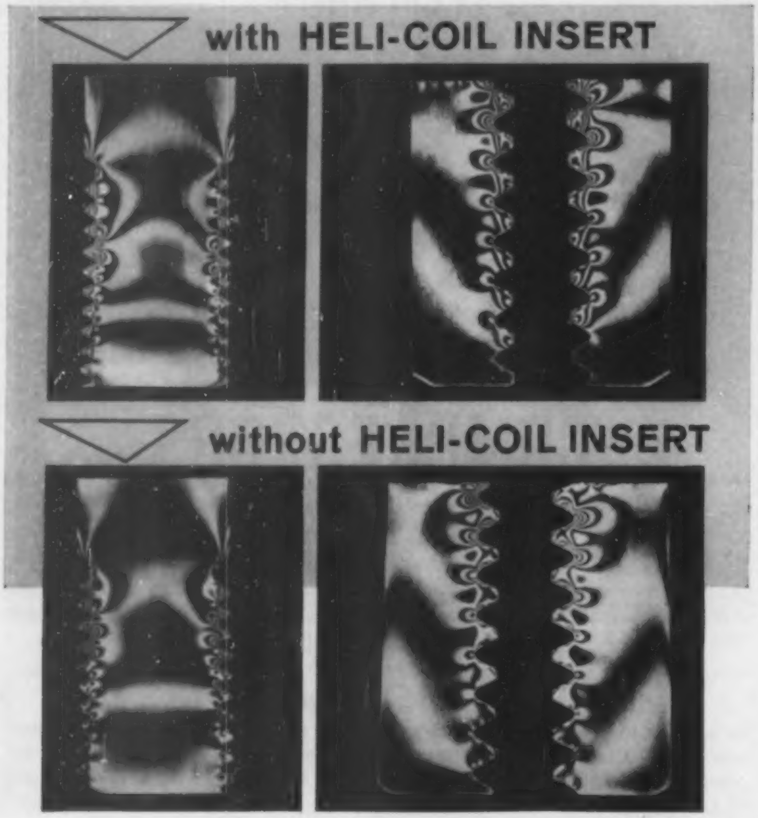
* Trade Mark . . . FLUR-O-FRAN, a special compound of TEFLON and other materials, having unique properties — highly resistant to chemical attack — wide temperature range, −350°F to +500°F — extremely low coefficient of friction.

† Registered Trade Mark for du Pont FLUOROCARBON Resins

FRANCE PACKING COMPANY
9925 BUSTLETON AVENUE
PHILADELPHIA 15, PA.

Circle 302 on Page 19

How HELI-COIL® Stainless Steel Wire Inserts Eliminate Stress Concentration and Insure Maximum Strength in Threaded Assemblies



Made of stainless steel wire, precision-rolled to a diamond-shaped cross-section, *Heli-Coil* screw thread Inserts provide two exclusive characteristics directly related to threaded assembly strength:

1. **Permanent, resilient threads between the threads of the male and female assembly members.** These eliminate stress concentrations (upper photos) by distributing the load evenly along the full length of thread engagement in both members. By contrast, note the sharp stress concentrations (lower photos) around the first two threads of the conventional assembly.

   NOTE: Diagrams at right show how *Heli-Coil* Inserts compensate for lead and angle error between female and male threads.

2. **A superior surface finish (8-15 RMS).** This holds friction loss to a minimum and, thus, provides maximum, consistent clamping load at any given wrench torque load.

RESULT: No stress concentration; improved fatigue strength in the male member; and a stronger assembly under all conditions.

There is a complete line of *Heli-Coil* products for every thread need: inserts, taps, tools and gages. Let us help with your design and application problems. Write today for complete information. 3146

HELI-COIL CORPORATION
512 Shelter Rock Lane, Danbury, Conn.

In Canada: ARMSTRONG BEVERLEY ENGINEERING LTD., 6975 Jeanne Mance St., Montreal 15, Que.

cated ball bearings as standard equipment. **Doerr Electric Corp.,** 507 N. Fourth Ave., Cedarburg, Wis.

Circle 566 on Page 19

Silicon Transistors

in new TO-46 subminiature package

Small-signal silicon transistors in TO-46 pancake package are only 0.070 in. high. One-third the height of the TO-18 package, TO-46 transistors maintain the same diameter and directly replace TO-18 devices. Maximum rating of the six transistors in the new series is 400 mw. Operating and storage temperature ratings are from −65 to +200 C. Three ranges of beta—20 to 50, 40 to 100, and 80 to 300—are available at a minimum breakdown voltage of 30 v and also 60v. **National Semiconductor Corp.,** 4 Thorpe St., Danbury, Conn.

Circle 567 on Page 19

Ball Bearing

has rubber-metal seal

Series KSP ball bearing for aircraft-control applications resists water, dust, and other contaminants. Bearing incorporates a rubber-metal seal, rather than a stainless-steel shield, used in former units to protect it against foreign matter. Maximum freedom of motion is re-

Circle 303 on Page 19

tained. Bearing accommodates misalignment due to initial setup and operational deflection in structure. **Fafnir Bearing Co.,** 37 Booth St., New Britain, Conn.

Circle 568 on Page 19

Rotary Switches

eliminate sliding or wiping action

Improved electromechanical rotary switches for timing, programming, sampling, commutating, and telemetering are available. Utilizing a new principle of contact actuation, switch design eliminates sliding or wiping action, enabling the unit to operate with little or no contact deterioration and essentially inde-

pendent of the speed of rotation. Performance is equally good in both directions of rotation; critical angular tolerances can be maintained in both directions. No auxiliary systems are required, and switch is entirely self-contained. **Electro-Miniatures Corp.,** 600 Huyler St., South Hackensack, N. J.

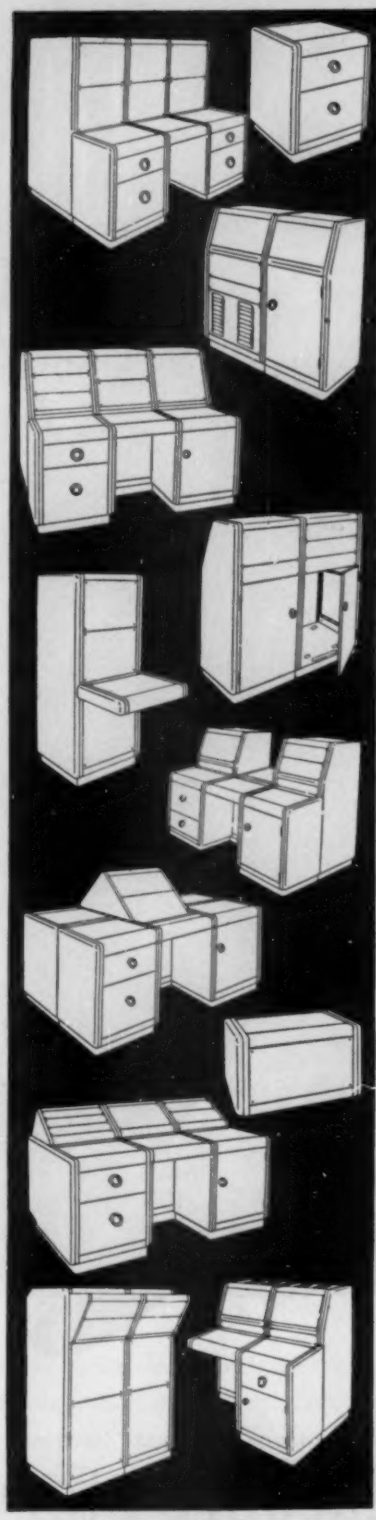
Circle 569 on Page 19

Control Valves

have flow rates to 16 cfm at 100 psi

New series of Slim Line miniaturized control valves afford maximum control flexibility in minimum space. They have flow rates to 16 cfm at 100 psi, exhausting to atmosphere. Suitable for manual, solenoid, or remote-pilot actuation, valves can be mounted singly for control of jigs and fixtures. Where multiple valves are required, they can be manifolded in banks of up to 16 valves, with valves mounted in any position. Common inlet-air supply can be fed

(Please turn to Page 192)



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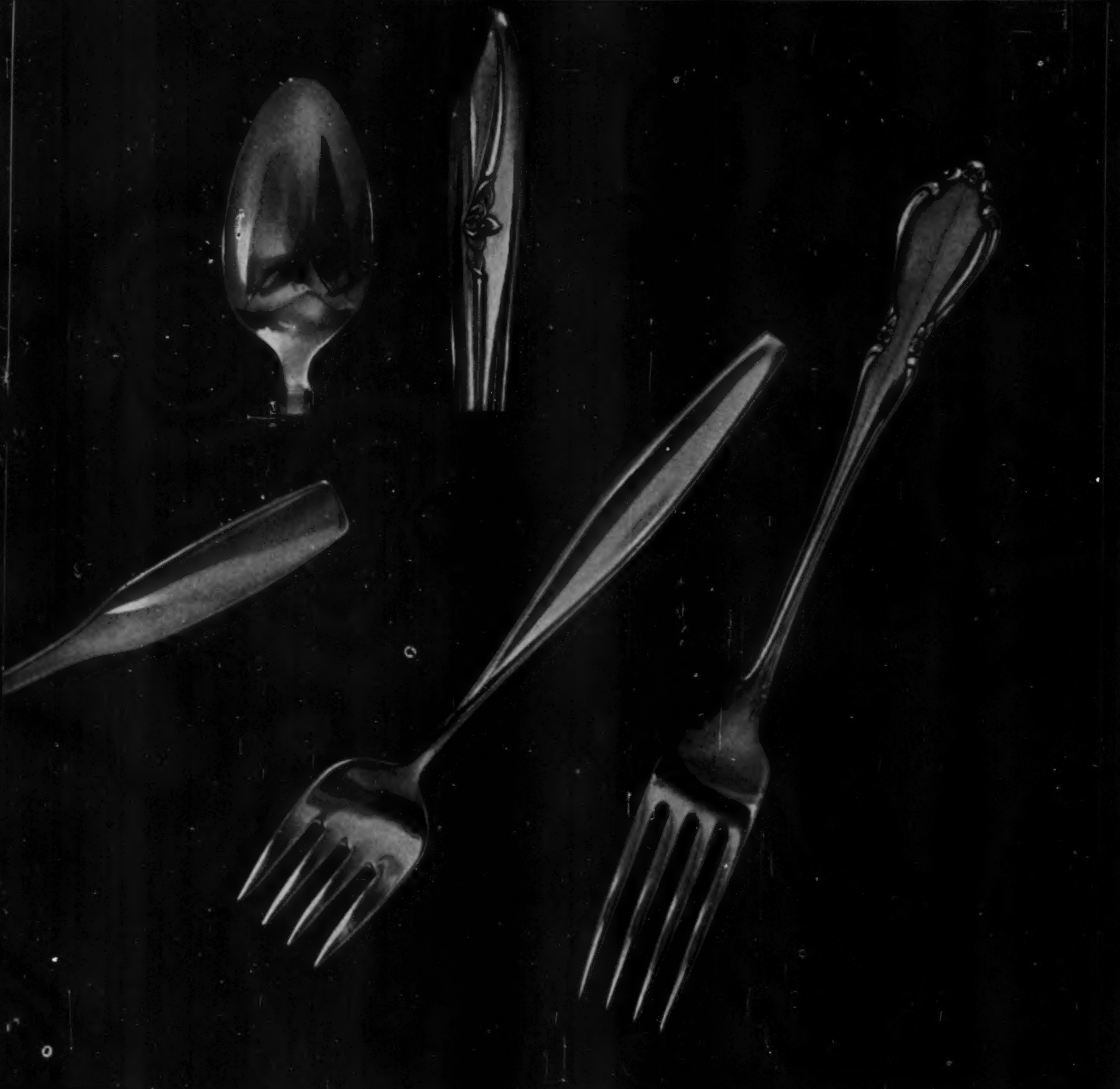
Circle 304 on Page 19

What the flatware story means to you

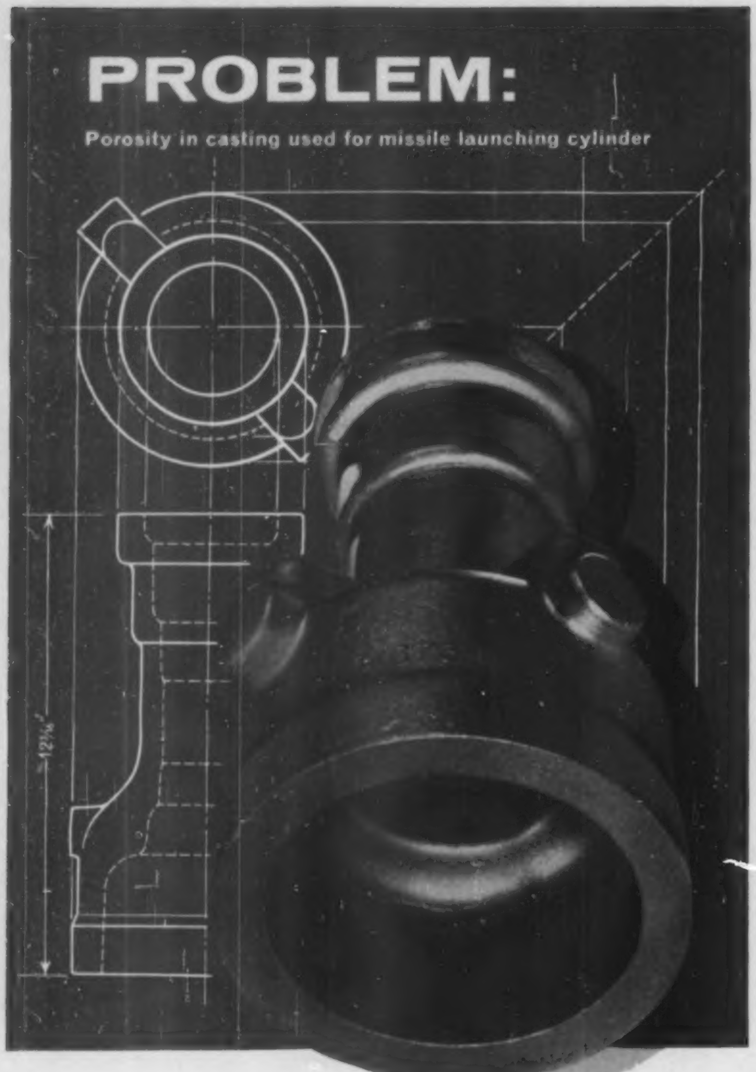


The elegance and exquisite beauty of Stainless Steel is steadily gaining in favor with the manufacturers of flatware. America's leading tableware craftsmen are specifying Sharon Stainless Steels more than ever. They find it easy to work with and like the natural patina it develops with age and use. In fact, they have found it to be the answer to the threat of foreign imports. For lasting durability, with an accent on product beauty, you'll be sure to find other manufacturers of high quality products also thinking Stainless Steels . . . and specifying them from the *Sharon Steel Corporation, Sharon, Pennsylvania.*

SHARON *Quality* **STEEL** SHARONSTEEL

AMERICA'S FOREMOST PRODUCER OF LIGHT STEELS

Circle 305 on Page 19



SOLUTION:

The problem of porosity was eliminated by the AmForge technical staff, who perfected a method to forge the part on an upsetter. The forged part did away with rejects, yet actually was produced at less cost than the casting it replaced. Performance of the part was greatly improved and the missile contractor realized definite savings.

If you have a similar problem part, consult AmForge. Write for our new brochure and the name of your AmForge Sales Engineer.

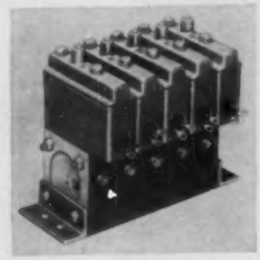
Remember: *your problems . . . our challenge!*

AM FORGE

a division of American Brake Shoe Company, 1220 West 119th Street, Chicago 43, Illinois. Two plants in Chicago, one in Azusa, California.

WHEN IT'S A VITAL PART, DESIGN IT TO BE FORGED

(*Continued from Page 189*)



from one or both ends. Valves are available in three and four-way types. They are suitable for air, oil, or water service at pressures to 125 psi and temperatures to 150 F. **Pneumatics Div., Bellows Valvair Inc., Div., IBEC,** 200 W. Exchange St., Akron 2, Ohio.

Circle 570 on Page 19

Nickel-Base Wire Cloth

for 1800 F service

Rene' 41, a nickel-base wire with high strength and oxidation resistance to 1800 F, is woven into wire cloth in a wide range of mesh, wire sizes, and types of weave. Cloth is available in widths from 24 to 48 in.; other widths can be furnished on special order. **National-Standard Co.,** Dept. RDT, Niles, Mich.

Circle 571 on Page 19

Germanium Mesa Switch

is high-speed unit in TO-18 case

TI 2N797 mesa transistor is an NPN germanium switch which has low saturation voltage, high gain-bandwidth product, and high-speed switching operation. Unit is packaged in a JEDEC standard TO-18 case. **Transistor Products Div., Texas Instruments Inc.,** P. O. Box 5012, Dallas 22, Tex.

Circle 572 on Page 19

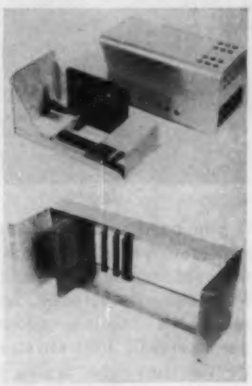
ENGINEERING DEPARTMENT

EQUIPMENT

Instrument Chassis

for prototype development

Five instrument (top) and rack-mounted (bottom) chassis accommodate from 6 to 44 standard printed-circuit Proto-Cards. All-aluminum Proto-Chassis are supplied as knock-down components, predrilled and tapped for easy, rapid assembly with a screwdriver. Only control-panel holes and mounting holes for special circuit elements need be



drilled. Instrument chassis include a six-card model with a 6 x 6-in. front panel and a ten-card model with a 6 x 8-in. front panel. Both are 12 ½ in. deep over-all, and have 2 ½-in. mounting bases. Rack-mounted model front panels measure 7 x 19 in.; 22-card model is 13 ½ in. deep and 44-card model, 18 in. deep. Rack-mounted card frame accommodates 22 cards with a rack space of 7 x 19 in., an opening of 17 in., and a depth of 7 ½ in. Circuit Structures Lab, P. O. Box 36, Laguna Beach, Calif.

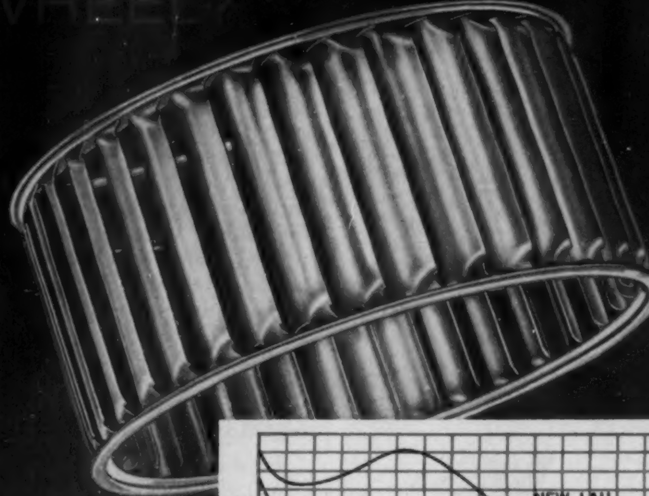
Circle 573 on Page 19

Drawing Leads

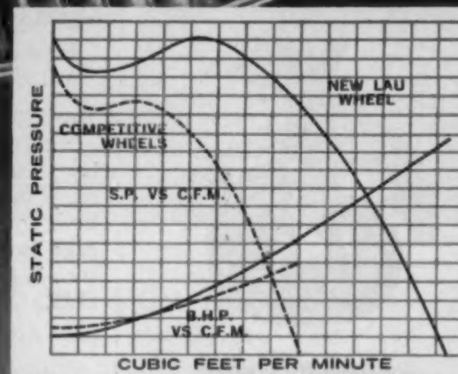
have new degree stamping

Damascus drawing leads are now available, two leads in a plastic tube, six tubes to a wrapped package. Two-lead containers allow drafts-

DO YOU NEED A HIGHER EFFICIENCY SMALL BLOWER WHEEL?



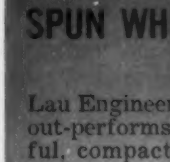
GET INCREASED PERFORMANCE WITH THE NEW LAU 4¾" to 8½" SPUN WHEEL



Lau Engineering has successfully developed a blower wheel that out-performs any wheel of comparable size tested. This powerful, compact unit is specifically designed for installation in room air conditioners but can be used effectively in most appliance applications. Lau "spun" construction contributes greatly to the wheel's structural rigidity and to a very high CFM to WATT ratio.

This new Lau wheel is offered in a customer's choice of aluminum, cold rolled steel or zinc grip and in a range of diameters, blade lengths, bore sizes and back plate designs.

LAU THE LAU BLOWER COMPANY
2027 Home Avenue Dayton 7, Ohio



Get this free engineering data file on the new Lau high performance appliance wheel.

Mr. Wm. H. Wentling, Director of Engineering
The Lau Blower Co., 2027 Home Ave., Dayton 7, Ohio

Please send me your engineering data file on the new Lau high performing wheel. ☐ We would like to see sample wheel.

Name____

Position____

Company Name____

Address____

Circle 307 on Page 19

THE

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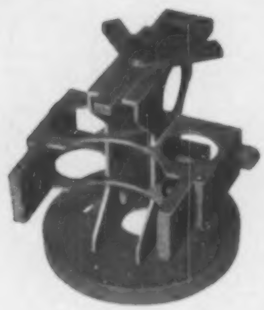

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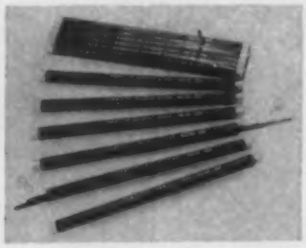


men to keep a selection of lead degrees at hand in a minimum of space, and hard plastic tubes prevent breakage. Individual tubes can be opened from either end, and each is stamped with the degree of the leads it contains. Each lead is printed with a black degree number on a yellow background for immediate recognition. Richard Best Pencil Co. Inc., Springfield, N. J.

Circle 574 on Page 19

Strain Gages

for use in temperatures to 180 F

Two 120-ohm, thin-paper base, wire strain gages are flat-grid types. S102 has a length of 3/32 in. and width of 1/8 in.; S103 is 7/64 in. square. Each grid is separately marked with gage factor and resistance. Metrix Inc., P. O. Box 683, Walnut Creek, Calif.

Circle 575 on Page 19

Direct-Reading Meter

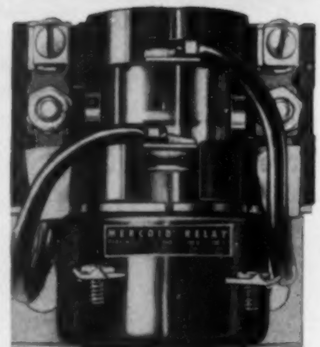
for air velocity and temperature

Flowtronic 55 provides direct, accurate reading of air velocity and air and surface temperature. Temperature measurement range is 20 to 220 F, and air velocity ranges are 0-1000, 1000-2000, and 2000-4000 fpm. Temperature scale is linear over entire range while velocity scale is linear at high veloci-

35 AMP

Plunger Type

MERCOID MERCURY RELAY



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240V.	20A.	10A.	240V.	25A.
440V.	8A.	—	440V.	10A.

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THE MERCOID CORPORATION,
4209 Belmont Ave.,
Chicago 41, Ill.

Circle 309 on Page 19

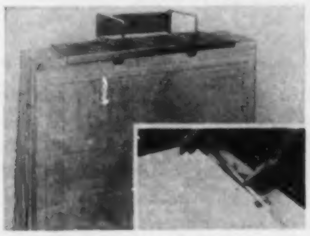
ties. Unit is useful in mechanical or electrical component cooling problems, and in air flow, cooling, and distribution studies, and similar applications. **Flow Corp.,** 11 Carleton St., Cambridge 42, Mass.

Circle 576 on Page 19

Vertical File

holds 100 drawings, plans, or prints of any size

Vertical Sheet File consists of a chrome wall rack which can be mounted wherever convenient, and ten aluminum binders to fit the rack. Each binder accommodates



from one to ten sheets of any size. Binder is opened or closed by loosening or tightening two wing nuts. **Plan Hold Corp.,** 5204 Chakemco St., South Gate, Calif.

Circle 577 on Page 19

Electronic Copier

is completely automatic

Arcor automatic electronic copying unit produces 1 to 500 clear copies from original copies or negatives in 10 sec each, at a paper cost of less than 5 cents per print. It permits the production of glossy prints of photos or line copy in an office machine. Process is rapid combination of fast, even exposure and processing with developing and stabilizing chemicals that produce high-quality photographic reproduction on heavy-weight photographic paper. Exposure section contains a lens-projection system designed to reproduce any original copy without haziness or uneven light exposure. Automatic applicators and squeegee rollers make the copy usable as it comes out of the copier. **Photorapid Corp.,** 142 Oregon St., El Segundo, Calif.

Circle 578 on Page 19

How *critical* can you be in your selection of a fastener for a special application . . . especially when extreme accuracy, reliability and consistent performance are specifications. For over thirty years, Chandler has been producing special fasteners and standard cap screws and bolts that meet these demanding requirements.

If you have a special fastener problem . . . here's what you can expect from Chandler. *Into the design* of your special fastener goes the knowledge of expert Chandler engineers . . . careful attention to detail and exhaustive testing to meet critical standards . . . advanced production methods to assure on-time delivery . . . RESULT . . . a precise fastener, custom-tailored and mass-produced at the most favorable cost.

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Circle 310 on Page 19

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Superior sealing with less wear and friction

The KAPSEAL twins, KIN and KEX, combine with a standard O-ring to improve sealing with better operating characteristics. These two are really mirror twins, KIN sealing on the ID and KEX sealing on the OD. Because of this you can take advantage of their potential in any sealing situation.

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The Teflon composition of the KAPSEAL twins give them the low breakout friction needed on standby mechanisms plus a low running friction for easy continuous operation.

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THE ENGINEER'S

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Recent Books

Electronic Equipment Design and Construction. *By Geoffrey W. A. Dummer, Cledo Brunetti, and Low K. Lee; 238 pages, 6 by 9 in., clothbound; published by McGraw-Hill Book Co., 330 West 42nd St., New York 36, N. Y.; available from* MACHINE DESIGN, $8.50 *postpaid.*

This manual provides recommended techniques and basic working data necessary for constructing electronic equipment from the initial stages of design through to testing the finished product. The major topics covered are structural and thermal design, use of materials, and the design techniques necessary to build electronic equipment to meet the performance requirements for both earth and space applications. Chapters in the book include basic design requirements, mechanical environments and their effect on electronic equipment, cooling of electronic equipment, electrical noise and shielding problems, component placement and circuit layouts, and modular geometry.

Shock and Vibration Handbook, 3 Volumes. *Edited by Cyril M. Harris, Columbia University, and Charles E. Crede, California Institute of Technology; 2028 pages, 6 by 9 in., clothbound; published by McGraw-Hill Book Co., 330 West 42nd St., New York 36, N. Y.; available from* MACHINE DESIGN, $47.50 *per set.*

All major phases of shock and vibration technology are presented for the solution of many engineering problems. There are 50 chapters, each pertaining to a particular facet of the technology and each written by one or more specialists. The first group of chapters provides a theoretical basis for shock and vibration. The second group considers instrumentation and measurements. The next group deals with analysis and testing-concepts in the treatment of data obtained from measurements, and procedures for analyzing and testing systems subjected to vibration and shock. Methods of controlling shock and vibration are discussed in a group

dealing with isolation, damping, and balancing. The final group of chapters discusses the nature of environmental conditions existing in various classes of vehicles and in circumstances where shock and vibration are transmitted through the air or ground.

Handbook of Chemistry and Physics, 43rd Edition. *Edited by Charles D. Hodgman; 3467 pages, 5 by 7½ in., clothbound; published by The Chemical Rubber Co., 2310 Superior Ave., Cleveland 14, Ohio;* $12.00 *per copy.*

This handbook presents, in condensed form, up-to-date information in the fields of chemistry and physics. The first of five sections presents mathematical tables including calculus and statistics. The second section provides properties of elements and physical constants. General chemical tables, heat and hygrometry, and quantities and units are covered in sections 3, 4, and 5. New materials have been added on thermal-neutron cross section, isothermal compressibility of liquids, physical constants of clear fused quartz, general values of physical constants, masses and mean lives of elementary particles. Tables for general use have been added, including the color code for electrical resistors, sound velocity in water above 212 F, and magnetic rotating power.

Government Publications

OTS Technical Reports. Copies of reports listed below are available from Office of Technical Services, U. S. Dept. of Commerce, Washington 25, D. C.

TR 60-254. The Evaluation of the Effects of Very Low Temperatures on the Properties of Aircraft and Missile Metals. By Leonard P. Rice, James E. Campbell and Ward F. Simmons, Battelle Memorial Institute; 50 pages, 8¼ by 10⅞ in., paperbound; $1.75 per copy.

This investigation presents the tensile and hardness properties of eight different alloys of interest to the aircraft and missile industries at temperatures ranging from —253 C (liquid hydrogen) to room temperature. These alloys are Ti-6Al-4V, Ti-4Al-3Mo-1V, Ti-16V-2.5Al, and B-120VCA titanium alloys; 17-7Ph, Ph15-7 Mo, and Type 301XH stainless steels; and Vascojet 1000 alloy steel. In general, values for hardness, elastic modulus, and tensile and yield strengths of these materials tended to increase as the test temperature was reduced to —253 C.

PB 161770. A New Type of Lightweight Cellular Material. By L. Polonsky and S. Lipson, Frankford Arsenal; 74 pages, 8 by 10½ in., paperbound; $1.75 per copy.

The object of this project was to investigate a method for producing a new type of cellular metal and to determine its strength properties and other characteristics. The process consists of preparing a refractory mold, filling the mold with soluble granules which correspond to the size and shape of the pores desired in the metal, and infiltrating the molten metal into this soluble aggregate. Potential applications for materials of this type are suggested.

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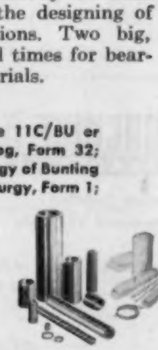

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DC Motor Control, by J. Ronald Wickey, 1961 (42 pp.) $1

AC Motor Control, by J. Ronald Wickey, and Arthur S. Newman, Jr., 1960-61 (40 pp.) $1

Preventing Fatigue Failures, by F. B. Stulen, H. H. Cummings, W. C. Schulte, 1961 (32 pp.) $1

Simplified Vibration Analysis by Mobility and Impedance Methods, by R. P. Thorn & A. H. Church, 1959-1960 (80 pp.) $2

Inside the Engineer, by Eugene Raudsepp, 1958-1960 (52 pp.) $1

Mobility of Cross-Country Vehicles, by M. G. Bekker, 1959-1960 (32 pp.) $1

Engineering Approach to Hydraulic Lines, by Jaroslav J. Taborek, 1959 (36 pp.) $1

Planning New Products, by Philip Marvin, 1953-1958 (102 pp.) $3

Friction-Clutch Transmissions, by Z. J. Zania, 1958 (30 pp.) $1

Design Guide—Flexible Couplings, by Leo F. Spector, 1958 (28 pp.) $1

Special Report on Electric Motors, Staff Report, 1958 (42 pp.) $1

Electronic and Electric Power Supplies (Symposium), 1958 (40 pp.) $1

Human-Factors Engineering, by J. D. Vandenburg and C. T. Goldsmith, 1958 (32 pp.) $1

Mechanics of Vehicles, by Jaroslav J. Taborek, 1957 (94 pp.) $2

Design for Fatigue Loading, by Joseph Marin, 1957 (34 pp.) $1

Hydraulic Servo Fundamentals, by J. M. Nightingale.
- Vol. 1, 1956 (32 pp.) $1
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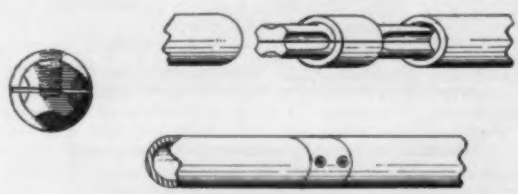
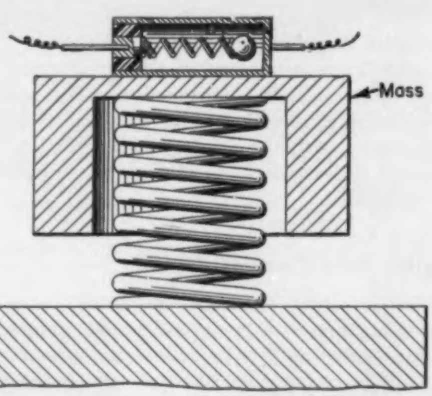
Expansible, double-ended plug provides a neat, flush connection between tubular sections. The plug, which is split at the center, has a cylindrical center section with reduced-diameter arms at each end. The surface of the arms is fluted. In assembly, the arms are inserted into the ends of the tubular sections to be connected. Set screws in the center section are then tightened, expanding the two plug halves. The fluted surfaces on the arms grip the inner surfaces of the tubular sections to lock the assembly against rotation and axial movement. *Patent* 3,000,656 *assigned to The Hollaender Mfg. Co., Cincinnati, Ohio by Peter R. Hollaender.*



Weak-Signal Vibration Detector

Spring-mounted mass amplifies weak sound signals of a predetermined frequency to actuate a vibratory switch. The cup-shaped mass which is mounted in inverted position to a spring attached to the base structure, carries the vibratory switch. A ball at the end of a helical spring serves as the switch contact element. When the spring-mass system is excited at resonant frequency by a weak sound signal transmitted through the base structure, the resulting vibratory motions move the ball contact against its case, closing the switch. The signal amplification provided by this arrangement



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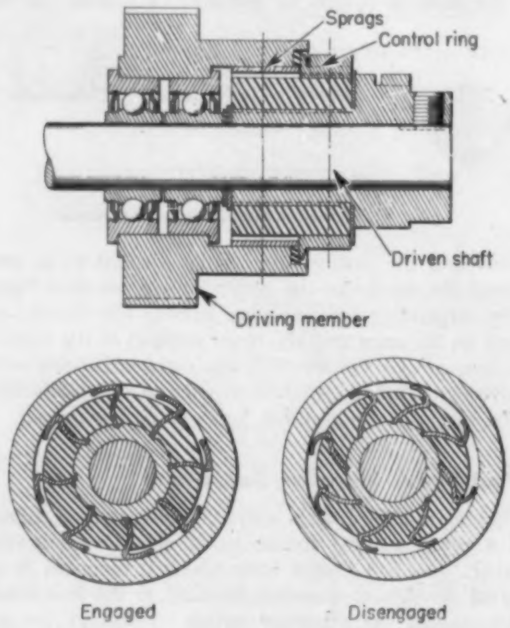
acts to increase the range of frequency response and sensitivity of the switch element. *Patent* 3,002,062 *assigned to the United States of America (Secretary of the Navy) by Samuel Globe.*

One-Way Clutch

Sheet-metal sprags embedded in a rubber or neoprene matrix are the power-transmitting elements in a one-way clutch that can be selectively engaged or disengaged. The L-shaped sprags are supported by the rubber matrix and ride in grooves on a sleeve which is attached to the driven shaft. Legs of the sprags extend beyond the matrix surface and, in the normal



operating position, engage the inner surface of a sleeve section on the driving member. To disengage the clutch, a control ring at one end of the sprag assembly is rotated relative to the driven shaft. The sprags move with the ring, pivoting in the grooves, to move out of engagement with the driving surface. *Patent* 2,998,874 *assigned to Soroban Inc., Melbourne, Florida, by John H. MacNeill.*

Digital Fluid Control Circuit

Multiple fluid lines are connected in parallel between a pump and motor to permit weighted control of flow according to a predetermined digital code. Each fluid line contains a solenoid-operated two-position valve and a restricting valve which governs the flow rate in the specific line. The number of fluid lines depends on the number of commands of the digital control signal which is used to specify motor speed. Thus, for the circuit shown, the three lines are used with a signal defined by not more than three digits. Be selective actuation of the control switches, any combina-

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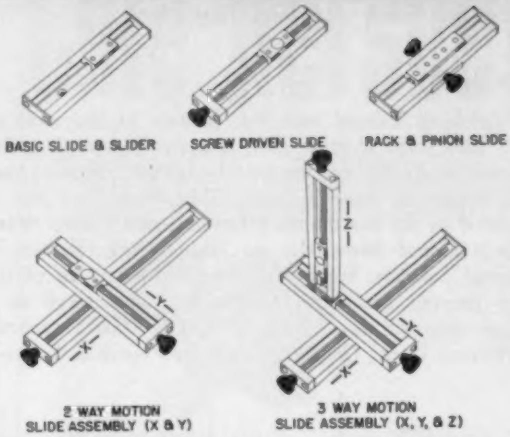

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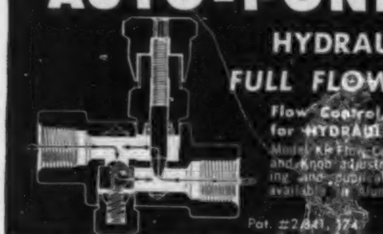

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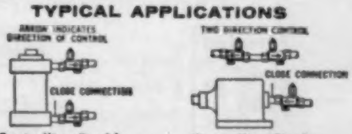

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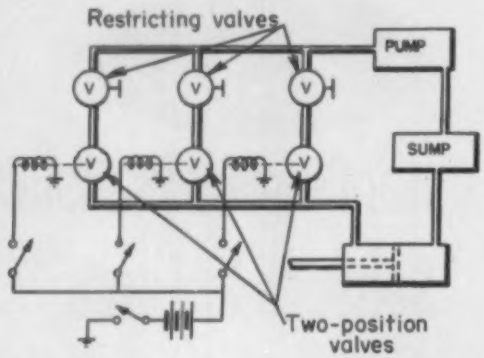

tion of flow lines may be opened to the motor input. If each of the restricting valves is set for a different flow rate, eight different flow rates (including zero flow) can be obtained at the motor input with the three-line arrangement. In digital-control systems based on the binary number system, two binary digits of a three-digit command may be assigned to each control switch. The switches may then be operated manually to designate the proper number, or automatically by a punched card or tape. *Patent* 2,999,482 *assigned to North American Aviation Inc. by John L. Bower.*

High-speed vane pump has sinusoidal rubbing surface which serves as cam to control vane position during rotation. Liquid is picked up by vanes in valleys of sinusoidal surface and swept into outlet ports at the lobe points. The rotor, which carrys the vanes, floats inside the stator chamber. *Patent* 2,985,110 *assigned to The Bendix Corp. by Farlow B. Burt, Chien-Bor Sung, and John R. Farron.*

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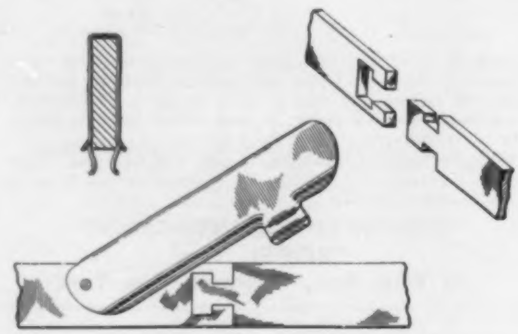

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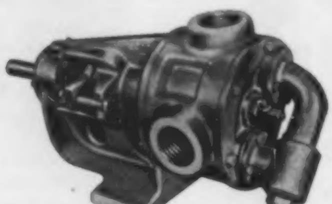
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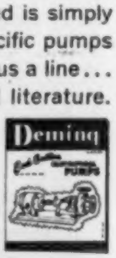

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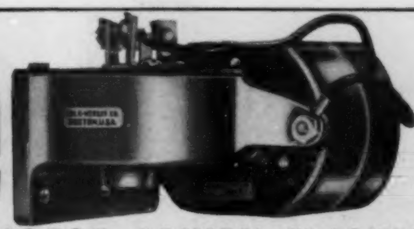

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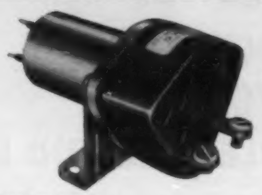

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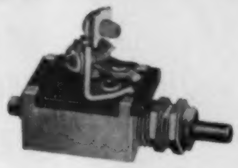

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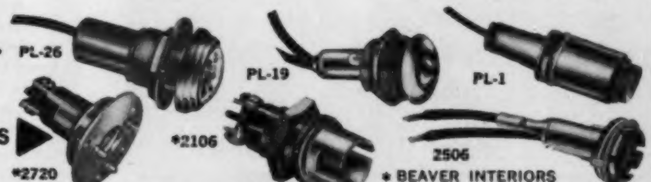

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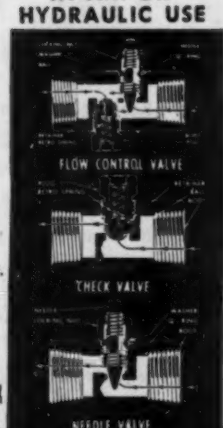

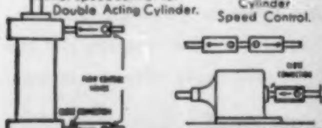

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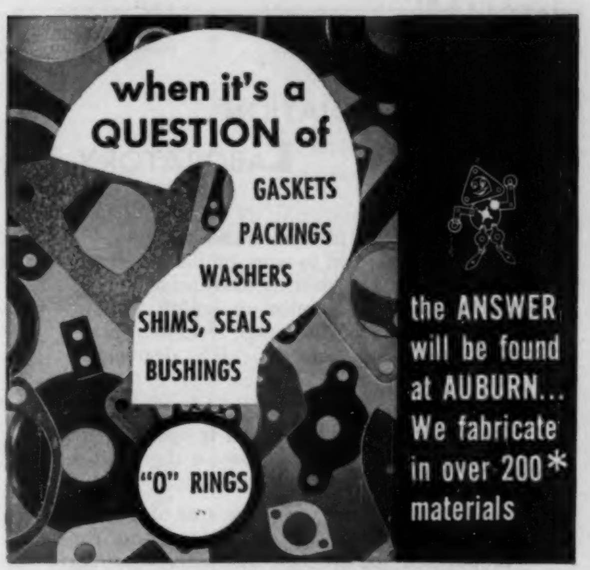

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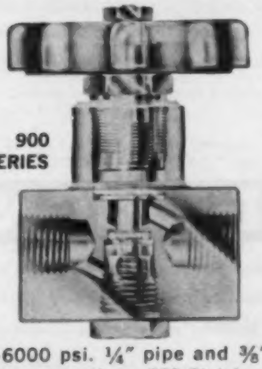

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Circle 334 on Page 19

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BPA NBP

backtalk—

—Some Like It Hot

This year, ASME established two awards to recognize outstanding members of the Heat Transfer Div. Next, a committee was formed to develop an appropriate design for a medal. One committee member, Dr. G. Horvay, apparently held a one-man brainstorming session, the result of which he reported to ASME:

"After mulling over my appointment to the Committee for Design of a Heat Transfer Division Award, I became keenly aware of the difficulty of proposing an award which is not named after some individual whose picture can decorate the medal. But there is no question in my mind that a figure of the Devil would be a most appropriate decoration, since throughout the ages no one has been more intimately connected with matters pertaining to heat transfer than the Devil. If there is reluctance on the part of the Division to dedicate the Heat Transfer Award to the Devil, I believe that the face of Kirchhoff or Prandtl, almost as important in heat transfer history as the Devil, would be appropriate medal decorations. If a more abstract design is preferred, the medal could, perhaps, suggest the three phases of heat transfer: Radiation (represented by the sun), convection (represented by a pot over a flame with liquid stirring in it), and conduction (represented by a metal bar partly immersed in a fire, the other end of the bar being held by a man who yells "OUCH!!" when the heat conducted reaches him). As a further alternative, three witches sitting on their brooms, stirring a pot of brew over a fire, would be suitable . . ."

The committee took a stand against the Devil. When the medal thing was straightened out, Dr. Novak Zuber, General Electric Co., was selected for the Heat Transfer Div. Memorial Award. The Max Jakob Memorial Award, highest ASME honor in the field of heat transfer, went to Prof. E. R. G. Eckert of the University of Minnesota.

—More Power to Fluid Power

Individuals' accomplishments in fluid-power technology or its application will henceforth be honored by the annual Achievement Award of the National Fluid Power Association. The first award is to be conferred in the fall of next year, and nominations are being accepted now. Achievements in the fields of oil hydraulics and pneumatics suitable for nominations may be in design of products or systems, basic or applied research, inventions, applications, processes, technical papers, education, marketing, or administration.

Complete information on the award, and nomination forms, may be obtained from National Fluid Power Association, 5595 N. Hollywood Ave., Milwaukee 17, Wis. Nominations must be submitted by April 30. The award winner will be selected by a conscientious twelve-man committee which includes Robert L. Hartford, publisher of MACHINE DESIGN.

—and Some Fluid, Drive Facts

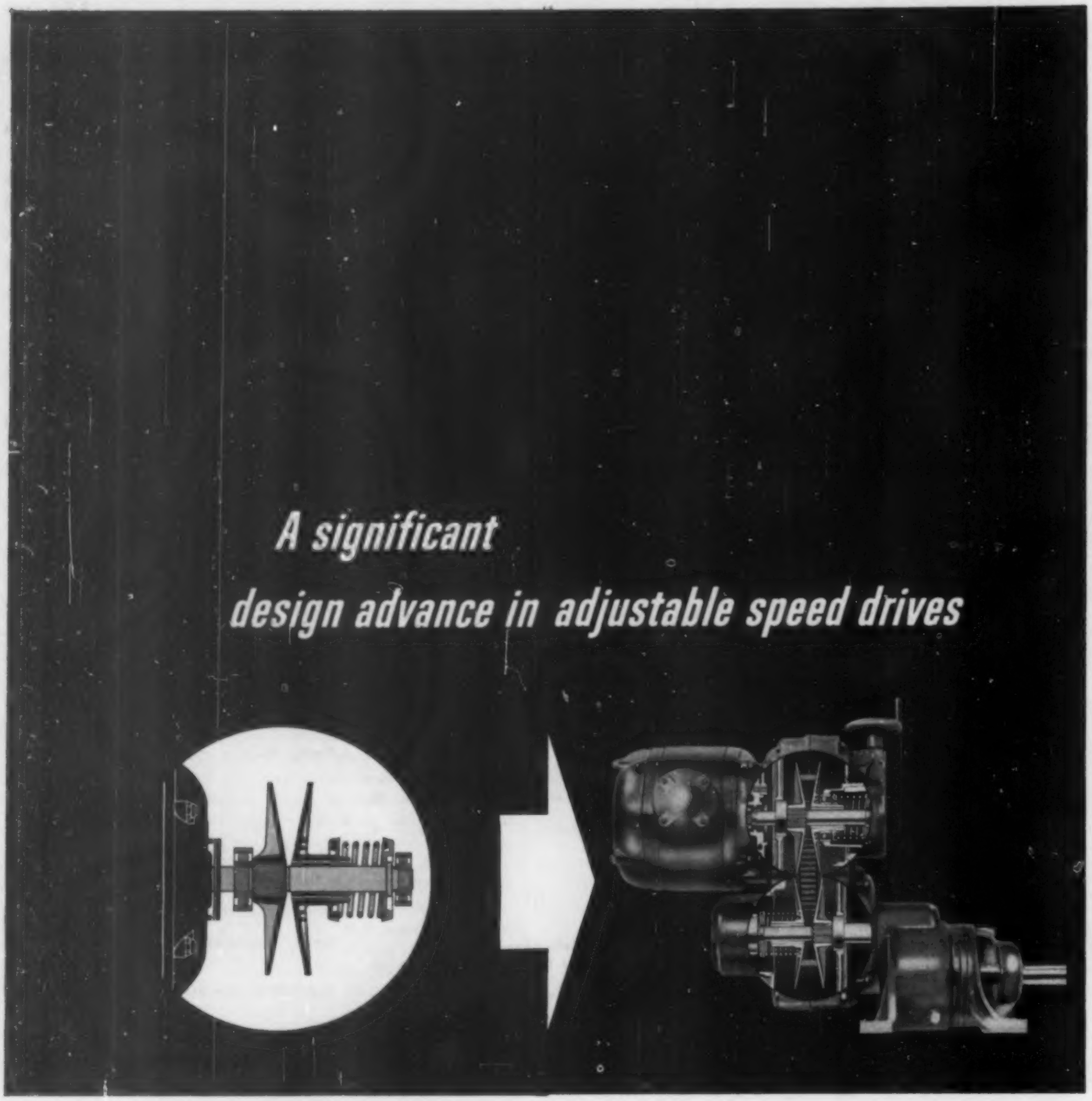
While we're on the subject of things fluid, let us pass along this tidbit from the Chrysler Corp. A 1962 Plymouth Savoy four-door sedan with V-8 engine, automatic transmission, radio, and heater has about 50 parts made of alloy steel, stainless, and aluminum. These parts weigh 192.6 pounds. The weight of a tankful of gasoline, engine coolant, automatic transmission fluid, engine oil, steering gear lubricant is 194.1 pounds. Further, the car's paint (a former fluid) weighs another 20.5 pounds.

—Yule Tidings

Did you notice that the cover of this just-before Christmas issue is subtly red and green? George Farnsworth, who built the cover and who therefore ought to know, says the question marks are there to ask, "Is there really a Santa Claus," even though that little paragraph on Page 3 talks of a tie-in with Mr. Raudsepp's article.

Now that we've mentioned Christmas, we may as well tell you—we're sending all our friends copies of MACHINE DESIGN this year. We hope they'll help you have a good 1962.

Advertising Index



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needs no lubrication, extends belt life, eliminates frozen pulleys

Electra engineers have devised a new torsion spring drive for cushioning normal operating shock and vibration. There are no splines or keyways . . . no possibility of frozen pulleys from fretting corrosion . . . and no need for lubrication. The adjustable pulley half simply glides along the drive shaft on a permanently-lubricated integral bushing. Since the pulley "gives", less heat is generated and belts last longer. Other features include chemically hard-faced aluminum pulleys to prevent scoring and dissipate frictional heat; interchangeable "Z" or "C" mounting arrangements, simple enough for field conversion; and 10:1 speed variation for 1/4, 1/2 and 3/4 HP. All-aluminum construction, including drive housing, makes the Electra-Drive the smallest, lightest, coolest-running FHP adjustable speed drive on the market today. Its advanced design features will give you years of versatile, trouble-free performance. Bulletin EM62-0 contains complete performance details and specifications. Write ELECTRA MOTORS, INC., 1110 N. Lemon St., Anaheim, California.

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A clear savings of 54%—as well as the elimination of a costly press fitting operation—was realized when the pin was redesigned by Pheoll. The part, formerly screw machined from two separate pieces of bar stock, force fitted together, is now reduced to a single unit through cold heading and secondary operations. Stronger, more wear resistant—and certainly more economical—this pin is another example of the full-range, cost-saving team service available from Pheoll.

Call Pheoll *now* for a quick rundown on your fastener problems.


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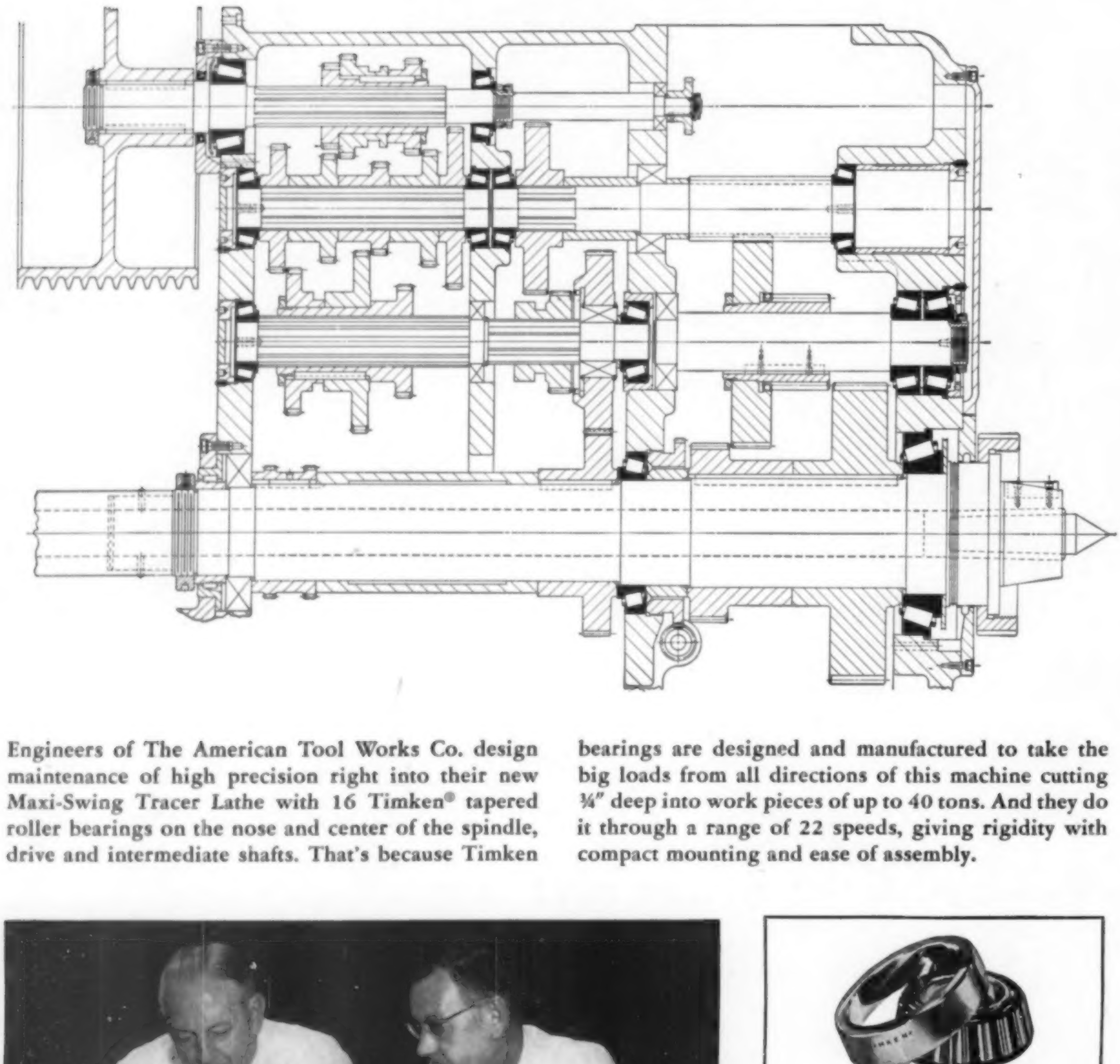
How world's largest tracer lathe assures precision



Engineers of The American Tool Works Co. design maintenance of high precision right into their new Maxi-Swing Tracer Lathe with 16 Timken® tapered roller bearings on the nose and center of the spindle, drive and intermediate shafts. That's because Timken bearings are designed and manufactured to take the big loads from all directions of this machine cutting ¾" deep into work pieces of up to 40 tons. And they do it through a range of 22 speeds, giving rigidity with compact mounting and ease of assembly.

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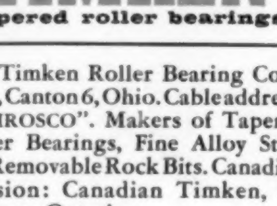

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